FINAL REPORT

OPTIMAL METHODS FOR FABRICATION OF GROUND BEEF

PREPARED FOR THE

U.S. ARMY NATICK RESEARCH AND DEVELOPMENT COMMAND

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BY THE

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GENERAL INTRODUCTION

In 1976, almost 50 percent of the total beef production was consumed as ground beef. This amounted to approximately 11 billion pounds. It is estimated that by 1980 this figure will exceed to 55 percent. Beef generated from cattle-fed grain supplied approximately 3 billion of the 10 billion pounds of ground beef derived from forage-fed beef. This forage-fed beef was predominately from USDA Utility or lower grade carcasses or from imported cow beef. USDA and military specifications require a minimum quality grade of U.S. Utility on beef used for ground beef. In 1976, Cross *et al*., reported that ground beef prepared from U.S. Utility or lower grade beef was unacceptable in tenderness. This lack of tenderness was primarily due to the amount of connective tissue in the product. It appears that some system should be devised so that a major portion of the connective tissue could be removed prior to formulation into a final product. This would ensure a product more acceptable in texture. Cross *et al*. (1977) investigated the effect of grinding plate size on textural properties of ground beef. Their results indicate that grinding method has a significant effect on tenderness and amount of connective tissue. The larger the initial plate size, the tougher the meat and the more connective tissue detected by the panel. Previous research in this laboratory (Cross *et al*. 1977) indicated that beef ground in the conventional manner (3/4 x 1/8 inch) yielded more detectable connective tissue than ground beef prepared with other methods of comminution.

Sensory panels found patties from U.S. Utility or lower beef to be unacceptably tough. Cross et al. (1978) investigated a new process called "desinewing" that removes most of the objectionable connective tissue during production of ground beef. These workers found that desinewing greatly improved the textural properties of beef patties produced from mature beef animals.

Since ground beef represents a sizeable portion of the meat dollar, it merits more research attention than it has been given. Little or no published data is available in the following areas:

1. The most suitable method of comminution for a particular grade or cut of meat;

2. The effect of temperature of raw material on product quality;

3. The effect of type and amount of fat on product quality;

4. The most suitable cooking method and patty size.

The Meat Science Research Laboratory has designed studies to answer these questions. The projects were divided into eight phases to be conducted over a period of two years. USDA contracted to complete three phases (I, II, and VI) with the U.S. Army Natick Research and Development Command. This final report will present the results by phase.

PROJECT PERSONNEL

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OVERALL SUMMARY & CONCLUSIONS

DESINEWING

1. Desinewing with the 0.19 cm - 0.25 cm stepped head reduced the Instron shear force, while improving sensory panel scores for all palatability traits when compared to grinding.

2. All four desinewing methods reduced the amount of soluble, insoluble and total collagen in raw patties when compared to grinding.

3. Data generated from this study indicates that desinewing results in a more acceptable product when compared to grinding.

4. Desinewing with the 0.19 cm head or the 0.19 - 0.25 cm stepped head improved the quality of chilled Cutter-Canner cow when compared to ground chilled Cutter-Canner beef. On the other hand, the palatability of hot Cutter-Canner cow beef patties was not improved by desinewing.

5. Desinewing of mature bull and Cutter-Canner cow meat produced a product of high quality (equal to Choice trimmings). Similar results were obtained when the lean was ground hot (unchilled).

HOT GROUND BEEF

6. Ground beef patties prepared from hot processed beef were more tender and juicy than patties prepared from chilled beef.

7. Total cooking loss was significantly less in the hot processed patties when compared to the chilled patties.

8. Hot processed patties had less configuration changes than chilled patties.

9. Ground beef prepared from hot-boned carcasses has bacteriological quality and shelf-life that are equal to or better than those of ground beef prepared from chilled carcasses.

FROZEN LEAN SOURCE

10. Frozen lean source had few practical effects on palatability or cooking properties.

PATTY SIZE

11. Patty size had significant effects on tenderness, juiciness, amount of detectable connective tissue, and flavor intensity. The 3.6 oz patties received significantly lower ratings in all of the aforementioned palatability traits when compared to the 4.0 and 8.0 oz patties.

PATTY TREATMENT

12. Patty treatment (knife, waffle, or plain) did not enhance any palatability trait. Untreated patties (plain) were more tender and juicy than patties receiving the knife or waffle treatment.

13. There appears to be no advantage (other than appearance) to subjecting the surface of the patty to a knife or waffle treatment. This data indicates that these treatments may actually have negative effects on palatability.

GRINDING VS FLAKING

14. Neither method of processing (grind vs flake) nor state of product when cooked for evaluation (precooked vs frozen-raw) exerted a practical effect on palatability, Instron values, or cooking characteristics in this study.

GRINDING VS CHOPPING

15. Generally, grinding, chopping or a combination of grinding and chopping as the initial particle reduction system did not greatly affect palatability, physical or chemical values.

16. There was some tendency for chopping to yield slightly higher tenderness scores and less detectable connective tissue than grinding.

FAT SOURCE & FAT LEVEL

17. As the percent fat increased from 16 to 30%, tenderness and juiciness scores increased.

18. Total cooking losses were not affected by fat level.

19. Type of fat did not affect the quality of ground beef.

STORAGE

20. The 9 months storage of ground beef patties containing 16, 20, 24, or 30% fat resulted in an increased incidence of off flavors and reduced tenderness and juiciness scores. The effects of various fat levels noted at 0 months remained about the same at all successive time intervals.

21. Source of fat had no significant affects on storage properties.

SHELF-LIFE

22. Storage time appeared to exert more influence on shelf-life than source of product or level of fat. However, formulations containing kidney and brisket fat had higher bacterial counts when formulated to 24% fat and were darker in color at the completion of the shelf-life study.

23. Higher incidences of off-odor were associated with higher levels of fat in the product.

PHASE I - PART 1

Objective: To determine the most suitable method of mechanical desinewing hot and chilled mature cow and bull beef for use in beef patties.

CHARACTERISTICS OF BEEF PATTIES AS INFLUENCED BY MECHANICAL DESINEWING CLASS OF BEEF TRIMMINGS AND HOT VS COLD BONING

Introduction

The consumption of ground beef has steadily increased over the past few years. It has been estimated that by 1980, 50% of the beef consumed in the U.S. will be consumed as ground beef. Cross et al. (1978b) reported that connective tissue was a major problem associated with the acceptance of ground beef. Patties formulated from Prime, Choice, and Good grade carcasses were rated as acceptable for the palatability traits of tenderness, connective tissue amount, and overall acceptability by a sensory evaluation panel (5.0 or above on a 9 point scale). On the other hand, patties from Utility and Cutter grades were rated as unacceptable in quality, (4.0 or less on 9 point scale). Since the major source of lean in ground beef is derived from mature animals, it would be desirable to improve the acceptability by removing the connective tissue. Some purchase specifications for ground beef do not presently permit the use of mature cow and bull beef in the formulations. A new technique has been developed whereby the connective tissue or sinew is removed. This technique is referred to as "mechanical desinewing." The objective of this study was to evaluate the effect of mechanical desinewing versus grinding on mature bull and cutter-canner cow beef, plus choice trimmings.

EXPERIMENTAL

Sixteen formulations of ground beef were manufactured by grinding or desinewing USDA Cutter-Canner cow chucks, mature bull chucks, Choice plates, and Choice trimmings. The raw materials were purchased at a local commercial packing plant and trucked to the Beehive Machinery laboratory at Sandy, Utah. Each raw material was ground through a 5.1 cm breaking plate. A random sample of 6.8 kg was taken during the 2 inch break and finely chopped for fat analysis by the Modified Babcock procedure. Fat content was standardized at 24% fat for desinewed treatments. Previous research by Cross et al. (1978) determined that desinewing removes 2-3% of the fat (Table 1).

GRINDING

Treatments were formulated to 22.7 kg by mixing the appropriate amount of lean and fat source for 3 min. CO_2 was added during the 3 min mix to reduce the temperature to 2-3 C. Following mixing treatments were either ground through a 0.32 cm plate or desinewed through either a 0.19 cm head, 0.25 cm head, 0.19 - 0.25 stepped head, or a 0.25 cm - 0.32 cm stepped head. All treatments were then formed into 145 g patties on a Hollymatic patty machine, placed in a box and frozen at -26 C. Within 2 weeks the boxed frozen patties were packed in dry ice and shipped via air freight to Beltsville, Md. Upon arrival, patties were wrapped in butcher paper, 3 patties per package, boxed and stored at -25° F.

COOKING PROCEDURES

Frozen patties were weighed, the diameter and height recorded, then broiled for 8 min on one side turned and broiled for 6 more min on the other side using electric Farberware grills (Model 450). Immediately following

broiling, patties were removed from the grill, temperature measured with a thermocouple, re-weighed, diameter and heighted re-measured to determine % cooking loss, % diameter change and % height change. Patties for sensory panel evaluation were sliced into eights and two slices were served hot to each panelist. Patties to be used for Instron Universal Shear were quartered, cooled to room temperature and then sheared to determine total work and peak shear force. Degree of doneness was evaluated by comparison with color photographs immediately after slicing.

CHEMICAL PROCEDURES

Ten patties per treatment were thawed until pliable and then passed through a 0.32 cm plate followed by a 0.24 cm plate. Triplicate samples were taken to determine the % fat and % moisture raw according to the AOAC approved procedure. Ten patties per treatment were cooked and subjected to the above mentioned technique to determine % fat cooked and % moisture cooked. Chemical connective tissue amount was determined according to the hydroxyproline procedure of Hill (1966) employing the color step of Bergman and Loxley (1963). Rancidity was determined by calculating the TBA number using the extraction procedure of Tarladgis et al. (1964). For the above mentioned chemical procedures, ten patties were powdered and duplicate samples per treatment were analyzed.

PANEL SELECTION AND TRAINING

An eight-member panel was selected and trained in descriptive attributes by the procedures of Cross et al. (1978). The panel rated the following attributes using an eight-point structured scale: a) initial and final tenderness, 8 = extremely tender and 1 = extremely tough; b) juiciness, 8 = extremely juicy and 1 = extremely dry; c) initial and final connective tissue

amount, 8 = none and 1 = abundant; d) ground beef flavor intensity, 8 = extremely intense and 1 = bland. Panelists rated four to six treatments at each of 24 sessions.

STATISTICAL ANALYSIS

Specific linear comparisons were made on each parameter evaluated to determine the effect of method of comminution and lean source on ground beef quality. The study was divided into three parts, (Table 2) each part will be discussed separately.

RESULTS & DISCUSSION

PART A: Four linear comparisons were made. Comparison 1 tested the effect of desinewing with the 0.19 cm head versus desinewing with the 0.25 cm head; Comparison 2 tested the effect of desinewing with the 0.19-0.25 cm head versus desinewing with the 0.25-0.32 cm head; Comparison 3 tested the effect of single aperture size versus double aperture size; and Comparison 4 tested the effect of grinding 0.32 cm versus desinewing. The effect of source along with the interaction of source with comparison was also tested.

Desinewed cutter-canner cow chucks were rated higher by sensory taste panel for initial and final tenderness when compared to grinding. Bull chucks on the other hand received slightly higher scores for initial tenderness when desinewed, but received lower scores for final tenderness when desinewed. Total shear work decreased for cutter-canner cow, while bull meat increased when desinewed (Figure 1). Among desinewing methods, the 0.19 cm head and 0.19-0.25 cm head produced higher initial and final and final tenderness scores for all raw materials when compared to other desinewing heads (Table 3). This result can be seen in Figure 2a, b where total shear work and shear force was less for bull and cow meat desinewed with the 0.19 cm head. The use of a double or stepped head reduced the shear force and total work to shear for bull meat when compared to a single head. The reverse was true for cutter-canner cow (Figure 2). The 0.19-0.25 cm stepped head significantly reduced total shear work and shear force ($P < .01$). However, grinding with the 0.32 cm plate significantly decreased shear force ($P < .01$) when compared to desinewing (Table 3). Sensory panel scores for juiciness were significantly higher ($P < .01$) for desinewing vs

grinding, with the 0.19 cm head higher than the 0.25 cm head. Removal of connective tissue would concentrate the lean tissue containing moisture. Ground beef flavor intensity followed the same pattern as juiciness (Table 3). The amount of detectable initial and final connective tissue amount decreased when desinewed for cutter-canner cow, however the opposite was true for bull meat (Figure 3a, b). Comparison 1 revealed that desinewing with the 0.19 cm head reduced the detectable connective tissue amount when compared with the 0.25 cm inch head (Figure 3 c, d). Desinewing with the 0.19-0.25 cm stepped head resulted in higher scores for initial and final connective tissue amount versus the 0.25-0.32 cm stepped head. Chemical determination of connective tissue, by hydroxyproline procedure produced similar results as was detected by sensory panel scores. The amount of insoluble and total collagen (mg/g) was reduced by desinewing with the 0.19 cm head compared to the 0.25 cm head. Insoluble collagen was less when the 0.19-0.25 cm head was used versus the 0.25-0.32 head (Figure 4b, c, d). While the sensory panel detected more final and initial connective tissue in desinewed versus ground bull meat, chemical determinations showed less connective tissue in desinewed meat. Cutter-canner cow had less chemically determined connective tissue and higher sensory scores when desinewed (Figure 5a, b). Desinewing with single aperture heads reduced the amount of insoluble and total collagen for both raw material (Table 5). Conversely, soluble collagen was higher when the single aperture head was used for bull meat compared to the stepped heads (Figure 4a).

The % change in height was more for patties produced from the 0.19 cm head versus 0.25 cm head. Likewise, patties from the 0.19-0.25 cm head underwent more height change (%) than patties from the 0.25-0.32 head regardless of whether the product was from bull or cow meat (Table 7).

Grinding bull meat decreased the % height change in contrast to desinewing while the opposite was true for cow meat (Figure 5c).

The % diameter change for cow meat was less when a stepped head was used vs a single head (Comparison 3), but the reverse was true for bull meat (Figure 5d). % Cooking loss was only significant for Comparison 1 ($P < .01$) with the 0.19 cm head resulting in more cooking loss than patties from the 0.25 cm head.

The % moisture of cooked patties was significantly more ($P < .01$) for for desinewed versus ground meat (Table 7). Within the four desinewing heads, use of stepped heads reduced the % moisture in bull meat. Among the two stepped heads, use of the 0.19-0.25 cm versus 0.25-0.32 cm increased the % moisture in cow meat. The single aperture 0.19 head (Comparison 1) reduced the % moisture for both sources of meat (Figure 6a, b, c).

CONCLUSIONS

In general, desinewing with the 0.19 cm or 0.19-0.25 cm stepped head reduced instron shear work and force, while improving sensory panel scores for all palatability traits when compared to grinding. Desinewing with the 0.100 inch head generally resulted in the least moisture loss, diameter change, height change and cooking loss. All four desinewing methods reduced the amount of soluble, insoluble, and total collagen in raw patties when compared to grinding. In general, bull meat yielded higher sensory scores for tenderness and connective tissue, less insoluble and total collagen, plus less total shear work and force. The data generated from this study generally indicates that desinewing with the 0.19 or 0.19-0.25 cm stepped head results in a more acceptable product when compared to grinding. Bull meat was preferred by the sensory panel to cutter-canner cow meat.

RESULTS AND DISCUSSION

PART B: The effect of hot versus chilled cutter-canner cow was tested with the same four linear comparisons as Part A. Comparison 1 = 0.19 cm head vs. 0.25 cm head; comparison 2 = 0.19-0.25 cm stepped head vs. 0.25-0.32 cm stepped head; comparison 3 = single aperture size vs. double aperture size; and comparison 4 = grind 0.32 cm vs. all desinew. The source of lean by method of comminution interaction was also tested.

Sensory panel scores for tenderness increased and Instron total work decreased when chilled cutter-canner cow was desinewed, as compared to grinding. However, the opposite was true for desinewed vs. ground hot cutter-canner cow beef (Figure 7a, b). Desinewed hot and chilled cutter-canner cow beef patties required significantly ($P < .01$) more force to shear when compared to ground beef (Table 9). Instron shear (^{2}Kg) increased for both chilled and hot cow meat when a stepped head vs. a single aperture head was used (Figure 7d). Initial and final tenderness was improved significantly ($P < .01$) when desinewed with the .19 cm head compared to the .25 cm head (Table 9). This is verified by Instron total work and shear force which decreased with the smaller aperture size (Figure 8c, d). Comparison 2, within stepped heads, revealed higher sensory scores for final tenderness when the 0.19-0.25 cm head was used regardless of the temperature of the beef (Table 9). Chilled and hot meat responded differently when desinewed with the 0.19-0.25 vs. 0.25-0.32 for Instron total work and shear force. Total work and shear force decreased for chilled cow as aperture size decreased, however total work and shear force increased for hot cow patties as aperture size decreased (Figure 8a, b).

Initial connective tissue amount, as detected by sensory panel, decreased when chilled cow meat was desinewed. Higher sensory scores reflect less detectable connective tissue. Conversely, the sensory panel detected more initial connective tissue (lower scores) when hot cow beef was desinewed (Figure 9a). Chemical determination of soluble, insoluble, and total collagen decreased for both hot and chilled cow meat when desinewed compared to ground (Figure 10a, b and Table 9). Initial and final connective tissue scores increased to a larger magnitude for hot meat compared to chilled when desinewed with the 0.19 cm head vs. the 0.25 cm head (Figure 9b, c). In addition, total and insoluble collagen was reduced by a larger magnitude when cow beef was desinewed with the 0.19 cm vs. 0.25 cm (Figure 10c, d). Soluble collagen was also less for beef desinewed with the 0.19 cm head vs. 0.25 cm head (Table 9). In this case, subjective sensory scores and objective chemical determination of connective tissue for comparison 1 paralleled each other. Final connective tissue scores were lower for hot cow meat desinewed with the 0.19-0.25 cm stepped head compared to the 0.25-0.32 cm stepped head. The reverse was true for chilled cow beef patties (Table 9). Generally, the amount of chemically determined insoluble and total collagen increased when chilled cow was desinewed with stepped vs. single aperture size heads. Conversely, when hot cow was desinewed with a stepped head, total and insoluble collagen decreased (Figure 11a, b). Juiciness scores increased when chilled cow meat was desinewed vs. ground, but scores for hot cow meat decreased for this comparison (Figure 12c). Within single aperture size heads, 0.25 cm desinewed hot cow beef product received higher scores than 0.19 cm desinewed hot cow beef. On the other hand 0.19 cm desinewed chilled cow beef received higher scores than 0.25 cm desinewed chilled cow patties (Table 9). Ground beef flavor intensity decreased for desinewed hot cow samples, but increased for desinewed chilled cow when compared to ground beef patties

(Figure 12d). The percent moisture in cooked samples decreased substantially when hot cow beef was desinewed with a double aperture stepped head compared to single aperture heads, while chilled cow changed very little in moisture attributable to desinewing method (Figure 12a). Within single aperture heads, 0.19 cm desinewed chilled cow beef patties decreased in percent moisture to a large degree while hot cow changed very little (Figure 11c). Within stepped heads, both hot and chilled cow beef patties increased in percent moisture cooked when desinewed with the 0.19-0.25 cm head (Figure 11d). The percent cooking loss decreased when chilled cow was desinewed with stepped heads vs. single aperture heads, but hot cow increased in percent cooking loss when desinewed with stepped heads vs. single aperture heads. Additionally, the percent cooking loss increased when desinewed with the 0.19 cm in head, vs. the 0.25 cm head (Table 9). The change in diameter of patties in cooking increased when hot and chilled meat were desinewed with the 0.19-0.25 cm head vs. the 0.25-0.32 cm in head (Table 9).

CONCLUSIONS

In general hot ground or 0.19 cm desinewed beef patties were, (1) rated higher by sensory panel for all palatability traits except flavor intensity; (2) received lower Instron total work and shear force readings; and (3) had less soluble, insoluble and total collagen than patties from chilled beef. Hot and cold boned cutter-canner cow when desinewed had less soluble, insoluble, and total collagen when compared to ground treatments. However, sensory panel scores for connective tissue amount did not reflect the removal of collagen by desinewing. Overall, desinewing with the 0.19 cm head or the 0.19-0.25 cm head improved the quality of chilled cutter-canner cow when compared to ground chilled cutter-canner cow beef. On the other hand, the palatability of hot cutter-canner cow beef patties was not generally improved by desinewing.

RESULTS AND DISCUSSION

PART C: This part dealt with comparisons of desinewing with the 0.19cm head vs grinding with a 0.32 cm plate using mature bull, chilled Cutter-Canner, and Choice trimmings. Specific linear comparisons were designed to test the effect method of comminution, bull vs Cutter-Canner cow (Comparison 51) and the average of bull plus Cutter-Canner cow vs Choice trimmings (Comparison 52). The interaction of method of comminution by comparison was also tested.

The effect of method of comminution was significant ($P< .01$) for final tenderness. Final sensory panel tenderness scores were improved by desinewing bull and cow meat, but reduced slightly by desinewing choice trimmings (Table 14). Initial tenderness was significant ($P <.01$) for the interaction of comminution x Comparison 51. Improvements in initial tenderness scores attributable to desinewing were greater for Cutter-Canner cow beef then bull meat. Scores for final tenderness followed the same pattern (Figure 13b). Instron total work was reduced by desinewing compared to grinding for all raw materials (Table 16). Bull meat patties required significantly ($P< .01$) less total shear work then Cutter-Canner cow patties. In addition, patties from Choice trimmings required significantly ($P< .01$) less total work then the average of all mature beef patties. Maximum shear force followed the exact same pattern as total shear work (Table 13). Sensory panel scores for initial connective tissue were significantly higher ($P< .01$) for bull meat patties (reflecting less connective tissue) when compared to Cutter-Canner cow regardless of comminution method. This was verified by the objective measurement of chemically determined insoluble and total collagen. Bull meat had less insoluble and total collagen then Cutter-Canner cow patties when produced by either method of comminution (Table 13). Soluble collegen was removed

from Choice trimmings to a larger degree then mature beef (Figure 13c).

Insoluble and total collagen were also substantially removed from Choice trimmings when compared to the average of bull and cow. This was evidenced by the steeper slope of the line for Choice beef patties (Figure 13d, 14a). Juiciness and ground beef flavor intensity were significantly (P< .01) higher for desinewed, patties made with the 0.19 cm head, vs ground meat (Table 14). Higher percentages of cooking loss were found for patties from Choice trimmings than product made from mature beef (Figure 14b). Conversely, the percent moisture in cooked desinewed Choice product was higher then that of mature beef patties (Figure 14c). The percent moisture in cooked Cutter-Canner cow patties was significantly (P <.01) higher then mature bull samples (Table 13). The percent change in patty height increased substantially for mature bull meat when desinewed, whereas Cutter-Canner cow product changed very little between grinding and desinewing (Figure 14d). Choice trimmings had a larger percent height change than mature beef (Table 13).

CONCLUSIONS

In general Choice trimmings received higher scores for all palatability traits followed closely by the scores of bull meat product. Cutter-Canner cow samples received the lowest sensory panel scores. Desinewing tended to increase palatability scores for all traits when compared with grinding. Desinewing also tended to reduce the amount of soluble, insoluble, and total collagen, plus reduce total Instron shear work and force. On the other hand, mechanical desinewing increased cooking losses and dimensional changes when compared to grinding. In general, sensory panel scores for initial and final connective tissue amount, scores were similar for product from Choice trimmings

and mature bull meat, with scores for Cutter-Canner cow being lower (Table 14). Conversely, chemical collagen as determined by the hydroxyproline procedure of Hill (1966) was highest in Choice trimmings, followed by Cutter-Canner cow and mature bull products displaying the least amount of chemically determined collagen (Table 15). This situation exemplifies the problems associated with a trained sensory taste panel being able to detect connective tissue in ground beef.

In summary, the desinewing of mature bull and Cutter-Canner cow does create a product of higher quality from a sensory standpoint. The best selection of desinewing heads would be the 0.19cm followed by the stepped (0.19 - 0.25 cm) head. Hot Cutter-Canner cow beef also creates high palatability ratings when ground. Data from this study indicates that the palatability of hot Cutter-Canner cow patties is reduced by mechanical desinewing.

TABLE 1. Ratio of lean to fat in treatment formulations.

Comminution Method	% Fat Prior to Comminution	% Lean	% Fat
		Mature Bull	Choice Plates
Grind	24	54	46
Desinew	27	46	54
		Cutter-Canner[a]	Choice Plates
Grind	24	48	52
Desinew	27	42	58
		Cutter-Canner	Choice Trimmings[b]
Grind	24	34	66
Desinew	27	25	75

[a] cutter-canner cow plus choice plates referred to as cutter-canner cow.

[b] cutter-canner cow plus choice trimmings referred to as choice trimmings.

TABLE 2. Experimental design.

PART A

Method of Comminution[a]	Chilled Mature Bull	Chilled Cutter-Canner Cow
Grind 0.32 cm	X	X
Desinew 0.19 cm[b]	X	X
Desinew 0.25 cm	X	X
Desinew 0.19-0.25 cm[c]	X	X
Desinew 0.25-0.32 cm	X	X

[a] aperture size

[b] single aperture size head

[c] stepped double aperture size head

PART B

Method of Comminution	Chilled Cutter-Canner Cow	Hot Cutter-Canner Cow
Grind 0.32 cm	X	X
Desinew 0.19 cm	X	X
Desinew 0.25 cm	X	X
Desinew 0.19-0.25 cm	X	X
Desinew 0.25-0.32 cm	X	X

TABLE 2. Experimental design. (Cont'd)

PART C

Method of Comminution	Chilled Cutter-Canner Cow	Chilled Mature Bull	Chilled Choice Trimmings
Grind 0.32 cm	X	X	X
Desinew 0.19 cm	X	X	X

TABLE 3. Sensory and Instron values for patties from bull and Cutter-Canner cow beef desinewed with different aperture-size heads.

Raw Material	INITIAL TENDERNESS Comparison 1		INITIAL TENDERNESS Comparison 2		FINAL TENDERNESS Comparison 1		FINAL TENDERNESS Comparison 2	
	Desinew 0.19 cm	Desinew 0.25 cm	Desinew 0.19-0.25 cm	Desinew 0.25-0.32 cm	Desinew 0.19 cm	Desinew 0.25 cm	Desinew 0.19-0.25 cm	Desinew 0.25-0.32 cm
Mature Bull	6.1^b	4.9^c	6.2^b	5.6^c	6.3^b	5.0^c	6.3^b	5.6^c
Cutter-Canner Cow	5.9^b	5.1^c	5.9^c	5.4^c	6.0^b	5.4^c	5.9^b	4.6^c
Average	6.0^b	5.0^c	6.0^b	5.5^c	6.1^b	5.3^c	6.0^b	5.4^c

Raw Material	TOTAL SHEAR WORK Comparison 2		SHEAR FORCE (kg) Comparison 2		SHEAR FORCE (kg) Comparison 4		INITIAL CONNECTIVE TISSUE AMOUNT Comparison 2	
	Desinew 0.19-0.25 cm	Desinew 0.25-0.32 cm	Desinew 0.19-0.25 cm	Desinew 0.25-0.32 cm	Grind	Average All Desinew	Desinew 0.19-0.25 cm	Desinew 0.25-0.32 cm
Mature Bull	38.3^b	44.1^c	6.3^b	7.0^c	5.5^b	7.1^c	5.8^b	4.9^c
Cutter-Canner Cow	43.8^b	55.8^c	7.7^b	9.9^c	7.3^b	8.0^c	5.1^b	4.6^c
Average	41.0^b	50.0^c	7.0^b	8.4^c	6.4^b	7.7^c	5.4^b	4.7^c

Raw Material	JUICINESS Comparison 1		JUICINESS Comparison 4		FINAL CONNECTIVE TISSUE AMOUNT Comparison 2	
	Desinew 0.19 cm	Desinew 0.25 cm	Grind 0.32 cm	Average All Desinew	Desinew 0.19-0.25cm	Desinew 0.25-0.32cm
Mature Bull	5.2^b	4.4^c	4.8^b	4.9^c	6.1^b	4.8^c
Cutter-Canner Cow	5.4^b	4.7^c	5.2^b	5.2^b	5.0^b	4.0^c
Average	5.3^b	4.6^c	5.0^b	5.1^c	5.4^b	4.2^c

b,c = paired means in the same row and comparison column followed by the same letter are not significantly different

TABLE 3. Sensory and Instron values for patties from bull and Cutter-Canner cow beef desinewed with different aperture-size heads. (Continued)

	GROUND BEEF			
	FLAVOR		INTENSITY	
	Comparison 1		Comparison 4	
	Desinew 0.19 cm	Desinew 0.25 cm	Grind 0.32 cm	Average All Desinew
Mature Bull	5.1^b	4.3^c	4.4^b	4.8^c
Cutter-Canner Cow	5.0^b	4.8^c	4.1^b	4.8^c
Average	5.0^b	4.6^c	4.2^b	4.8^c

b,c = paired means in the same row and comparison column followed by the same letter are not significantly different ($P < 0.01$).

TABLE 4. Sensory values for ground vs desinewed patties made from bull and cutter-canner cow beef.

Method of Comminution	Initial Tenderness		Final Tenderness		Initial Connective Tissue Amount		Final Connective Tissue Amount		Juiciness		Ground Beef Flavor Intensity	
	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner
Grind 0.19 cm	5.6	4.5	6.0	4.7	5.7	4.2	6.0	4.2	4.8	4.4	4.4	4.1
Desinew 0.25 cm	6.1	5.9	6.3	6.0	6.0	5.2	6.4	4.8	5.2	5.4	5.1	5.0
Desinew 0.32 cm	4.9	5.1	5.0	5.4	4.8	5.0	4.6	4.7	4.4	4.7	4.3	4.8
Desinew 0.19-0.25 cm	6.2	5.9	6.3	5.9	5.8	5.1	6.1	5.0	5.0	5.3	4.9	4.7
Desinew 0.25-0.32 cm	5.6	5.4	5.6	4.6	4.9	4.6	4.8	4.0	5.0	5.3	4.8	4.7

TABLE 5. Chemical collagen values for bull and cutter-canner cow beef.

Raw Material	Insoluble Collagen mg/g		Total Collagen mg/g	
	Comparison[a] 3		Comparison[a] 3	
	Single	Double	Single	Double
Mature Bull	9.4[c]	11.8[d]	11.4[c]	13.2[d]
Cutter-Canner Cow	14.4[c]	16.4[d]	16.0[c]	18.1[d]
Average	12.0[c]	14.1[d]	13.5[c]	15.6[d]

[a] single aperture size (0.19 cm and 0.25) or double aperture size (0.19-0.25 cm) or (0.25-0.32 cm).

[c, d] paired means in the same row and comparison column followed by the same letters are not significantly different.

TABLE 6. Chemical composition for bull and cutter-canner cow beef.

Method of Comminution	% Fat Raw		% Moisture Raw		% Fat Cook		% Moisture Cook		Soluble Collagen mg/g		Insoluble Collagen mg/g	
	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner
Grind 0.19 cm	25.2	23.5	59.6	62.0	26.6	23.2	46.0	50.0	2.1	2.1	18.6	25.7
Desinew 0.25 cm	23.6	25.7	60.7	60.3	22.4	21.0	48.9	52.9	1.5	1.4	7.1	13.9
Desinew 0.32 cm	22.9	24.2	60.3	59.7	25.4	23.8	64.6	64.5	2.5	1.6	11.7	15.0
Desinew 0.19-0.25 cm	21.6	24.2	62.8	60.9	22.6	21.4	51.7	67.1	1.8	1.9	10.4	16.2
Desinew 0.25-0.32 cm	25.9	24.0	58.8	61.0	21.3	21.9	51.5	51.3	1.0	1.6	13.2	16.5

Method of Comminution	Total Collagen mg/g	
	Bull	Cutter Canner
Grind 0.19 cm	20.7	27.8
Desinew 0.25 cm	8.6	15.3
Desinew 0.32 cm	14.2	16.6
Desinew 0.19-0.25 cm	12.2	18.1
Desinew 0.25-0.32 cm	14.2	18.1

TABLE 7. Physical measurements of patties for bull and Cutter-Canner cow beef desinewed with different aperture size leads.

Raw Material	% Height Change				% Cooking Loss		% Moisture Cook	
	Comparison 1		Comparison 2		Comparison 1		Comparison 4	
	Desinew 0.19 cm	Desinew 0.25 cm	Desinew 0.19-0.25cm	Desinew 0.25-0.32cm	Desinew 0.19 cm	Desinew 0.25 cm	Grind	Average All Desinew
Mature Bull	22.9^{b}	16.4^{c}	20.9^{b}	12.9^{c}	41.8^{b}	37.9^{c}	46.0^{b}	54.2^{c}
Cutter-Canner Cow	21.8^{b}	18.6^{c}	21.4^{b}	19.2^{c}	43.1^{b}	41.2^{c}	50.0^{b}	59.0^{c}
Average	22.4^{b}	17.5^{c}	21.2^{b}	16.0^{c}	42.5^{b}	39.9^{c}	48.0^{b}	56.6^{c}

b, c paired means in the same row and comparison column followed by the same letter are not significantly different ($P < .01$).

TABLE 8. Physical measurements for ground vs desinewed patties made from bull and Cutter-Canner cow beef.

Method of Comminution	% Diameter Change		% Height Change		Total Shear Work		Shear Force kg		Cook Temperature C°		% Cooking Loss	
	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner	Bull	Cutter Canner
Grind 0.19 cm	22.5	22.0	12.9	20.7	40.9	52.3	5.5	7.3	75.1	67.1	40.5	41.7
Desinew 0.25 cm	22.2	22.8	22.9	21.8	39.1	42.7	5.8	7.1	73.5	68.2	41.8	43.1
Desinew 0.32 cm	20.5	23.0	16.4	18.6	57.2	46.3	9.5	7.6	66.4	73.6	37.9	41.2
Desinew 0.19-0.25 cm	22.3	22.7	20.9	21.4	38.3	43.8	6.3	7.7	65.7	65.8	38.5	40.0
Desinew 0.25-0.32 cm	24.2	21.6	12.9	19.2	44.0	55.8	7.0	9.9	71.1	70.1	41.4	40.0

Method of Comminution	Degree of Doneness	
	Bull	Cutter Canner
Grind 0.19 cm	2.1	2.4
Desinew 0.25 cm	2.0	2.0
Desinew 0.32 cm	2.1	2.1
Desinew 0.19-0.25 cm	2.4	2.2
Desinew 0.25-0.32 cm	2.2	2.3

TABLE 9. Palatability, physical and chemical values for patties from hot and cold boned cutter-canner cow and bull meat desinewed by different methods

Raw Material	INITIAL TENDERNESS Comparison 1 Desinew 0.19 cm	INITIAL TENDERNESS Comparison 1 Desinew 0.25 cm	FINAL TENDERNESS Comparison 1 Desinew 0.19 cm	FINAL TENDERNESS Comparison 1 Desinew 0.25 cm	FINAL TENDERNESS Comparison 2 Desinew 0.19-0.25 cm	FINAL TENDERNESS Comparison 2 Desinew 0.25-0.32 cm	INSTRON SHEAR FORCE (Kg) Comparison 4 Grind	INSTRON SHEAR FORCE (Kg) Comparison 4 Average all desinew
Hot Cutter-Canner	6.2^b	4.9^c	6.3^b	4.8^c	6.3^b	6.0^c	7.4^b	8.2^c
Cold Cutter-Canner	6.0^b	5.2^c	6.0^b	5.4^c	5.9^b	5.4^c	7.3^b	8.1^c
Average	6.1^b	5.1^c	6.2^b	5.1^c	6.1^b	5.7^c	7.3^b	8.1^c

Raw Material	FINAL CONNECTIVE TISSUE AMOUNT Comparison 2 Desinew 0.19-0.25 cm	FINAL CONNECTIVE TISSUE AMOUNT Comparison 2 Desinew 0.25-0.32 cm	SOLUBLE COLLAGEN MG/G Comparison 4 Grind	SOLUBLE COLLAGEN MG/G Comparison 4 Average Desinew	SOLUBLE COLLAGEN MG/G Comparison 1 Desinew 0.19 cm	SOLUBLE COLLAGEN MG/G Comparison 1 Desinew 0.25 cm	PERCENT COOKING LOSS Comparison 1 Desinew 0.19 cm	PERCENT COOKING LOSS Comparison 1 Desinew 0.25 cm
Hot Cutter-Canner	4.8^b	5.0^c	1.4^b	1.0^c	$.70^b$	1.4^c	43.2^b	41.6^c
Cold Cutter-Canner	5.0^b	4.0^c	2.1^b	1.6^c	1.4^b	1.6^c	43.1^b	41.2^c
Average	4.9^b	4.5^c	1.8^b	1.3^c	1.0^b	1.5^c	43.1^b	41.4^c

Raw Material	% DIAMETER CHANGE Comparison 2 Desinew 0.19 0.25 cm	% DIAMETER CHANGE Comparison 2 Desinew 0.25 0.32 cm	JUCINESS Comparison 1 Desinew 0.19 cm	JUCINESS Comparison 1 Desinew 0.25 cm
Hot Cutter-Canner	24.2^b	21.6^c	5.2^b	5.4^c
Cold Cutter-Canner	22.7^b	21.6^c	5.4^b	4.7^c

b,c = paired means in the same row and comparison column followed by the same letter are not significantly different (P> .01)

TABLE 10. Sensory panel values for patties from ground vs. desinewed hot and cold boned cutter-canner cow and bull meat

Method of Comminution	TENDERNESS		TENDERNESS		CTA[a]		CTA		JUCINESS		GB[b] FLAVOR INTENSITY	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
Grind 0.32 cm	4.5	6.4	4.7	6.4	4.2	5.8	4.2	5.2	4.4	5.8	4.1	5.3
Desinew 0.19 cm	6.0	6.2	6.0	6.3	5.2	5.7	4.8	5.9	5.4	5.2	5.0	4.2
Desinew 0.25 cm	5.2	4.9	5.4	4.8	5.0	4.3	4.7	3.6	4.7	5.4	4.8	4.9
Desinew 0.19-0.25 cm	5.9	6.2	5.9	6.3	5.1	5.4	5.0	4.8	5.3	5.6	4.7	5.2
Desinew 0.25-0.32 cm	5.4	6.0	5.4	6.0	4.6	5.4	4.0	5.0	5.3	5.4	4.7	4.9

a = connective tissue amount.

b = ground beef flavor intensity.

TABLE 11. Physical measurements for patties from hot and cold boned cutter and canner cow and bull meat either ground or desinewed

Method of Comminution	PERCENT DIAMETER CHANGE		PERCENT HEIGHT CHANGE		PERCENT COOKING LOSS		DEGREE OF DONENESS		COOKED TEMPERATURE °C		INSTRON TOTAL WORK		INSTRON SHEAR FORCE (Kg)	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
Grind 0.32 cm	22.0	23.7	20.7	19.5	41.7	43.3	2.4	2.2	67.1	66.4	52.3	40.4	7.3	7.4
Desinew 0.19 cm	22.8	20.8	21.8	25.0	43.1	43.2	2.1	2.7	68.2	68.6	42.7	34.0	7.0	6.3
Desinew 0.25 cm	23.0	22.1	18.6	25.0	41.2	41.6	2.1	2.4	66.7	65.9	46.3	57.5	7.6	9.9
Desinew 0.19–0.25 cm	22.7	24.2	21.4	20.6	40.0	43.4	2.2	2.2	65.8	69.6	43.8	45.6	7.7	8.8
Desinew 0.25–0.32 cm	21.6	21.6	19.2	21.3	40.0	43.4	2.3	2.2	70.1	66.8	55.8	42.7	9.9	8.2

TABLE 12. Chemical measurements for patties from hot and cold boned cutter and canner cow and bull meat either ground or desinewed

Method of	PERCENT FAT RAW		PERCENT MOISTURE RAW		PERCENT FAT COOK		PERCENT MOISTURE COOK		SOLUBLE COLLAGEN MG/G		INSOLUBLE COLLAGEN		TOTAL COLLAGEN	
Comminution	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
Grind 0.32 cm	23.5	29.2	62.0	56.6	23.2	20.9	49.9	53.3	2.1	1.4	25.7	19.3	27.8	20.7
Desinew 0.19 cm	25.8	27.0	60.3	58.7	20.9	23.0	52.9	67.4	1.4	.70	13.9	10.8	15.3	11.5
Desinew 0.25 cm	24.2	24.8	59.7	60.4	23.8	22.3	64.5	67.9	1.6	1.4	15.0	18.6	16.6	20.0
Desinew 0.19-0.25 cm	24.2	25.6	60.8	60.4	21.4	19.6	67.1	52.5	1.9	1.0	16.2	12.8	18.1	13.8
Desinew 0.25-0.32	24.1	23.9	61.0	62.1	21.9	22.7	51.3	51.1	1.6	1.0	16.5	13.5	18 2	14.5

TABLE 13. Palatability, physical and chemical values for patties from bull, canner and cutter cow and choice beef either ground or desinewed.

Method of Comminution	Initial Connective tissue amount		Total Shear Work				Shear Force (Kg)			
	Comparison 51		Comparison 51		Comparison 52		Comparison 51		Comparison 52	
	Bull	Cow	Bull	Cow	Average Bull+cow	Choice	Bull	Cow	Average Bull+cow	Choice
Ground 0.32 cm	5.7^{b}	4.2^{c}	40.9^{b}	52.3^{c}	46.6^{b}	31.4^{c}	5.5^{b}	7.3^{c}	6.4^{b}	5.3^{c}
Desinew 0.19 cm	6.0^{b}	5.2^{c}	39.1^{b}	42.7^{c}	40.9^{b}	29.4^{c}	5.8^{b}	7.0^{c}	6.5^{b}	4.2^{c}
Average	5.8^{b}	4.7^{c}	40.0^{b}	47.5^{c}	43.8^{b}	30.4^{c}	5.6^{b}	7.1^{c}	6.4^{b}	4.8^{c}

Method of Comminution	Insoluble Collagen MG/G		Total Collagen MG/G		% Mositure Cook		% Height	
	Comparison 51		Comparison 51		Comparison 51		Comparison 52	
	Bull	Cow	Bull	Cow	Bull	Cow	Bull	Cow
Ground 0.32 cm	18.6^{b}	25.7^{c}	20.7^{b}	27.8^{c}	46.0^{b}	50.0^{c}	16.8^{b}	23.8^{c}
Desinew 0.19 cm	7.1^{b}	13.9^{c}	8.6^{b}	15.3^{c}	48.9^{b}	52.9^{c}	22.4^{b}	30.9^{c}
Average	12.8^{b}	19.8^{c}	14.6^{b}	21.6^{c}	47.4^{b}	51.4^{c}	19.6^{b}	27.4^{c}

b, c paired means in the same row and comparison column followed by the same letter are not significantly different ($P > .01$).

TABLE 14. Palatability ratings for patties made from bull, cutter and canner cow and choice beef either ground or desinewed.

	Initial Tenderness			Final Tenderness			Initial Connective Tissue Amount			Final Connective Tissue Amount			Juiciness			Ground beef Flavor Intensity		
	CH[b]	B	C	CH	B	C	CH	B	C	CH	B	C	CH	B	C	CH	B	C
Grind 0.32cm	5.6	5.6	4.5	6.2[c]	6.0[c]	4.7[c]	5.6	5.7	4.2	5.6	6.1	4.2	4.0[c]	4.8[c]	4.4[c]	3.7[c]	4.4[c]	4.1[c]
Desinew 0.19cm	5.8	6.1	6.0	6.0[d]	6.4[d]	6.0[d]	5.8	6.0	5.2	5.6	6.4	4.8	5.3[d]	5.2[d]	5.4[d]	5.4[d]	5.1[d]	5.0[d]

[b] CH = choice trimmings, B = mature bull, C = chilled cutter-canner cow

[c,d] paired means in the same column with the same letters are not significantly different (P>.01).

TABLE 15. Chemical values for patties from bull, cutter and canner cow and choice beef either ground or desinewed.

	% Fat Raw			% Moisture Raw			% Fat Cook			% Moisture Cook			Soluble Collagen MG/G		
	CH[a]	B	C	CH	B	C	CH	B	C	CH	B	C	CH	B	C
Grind 0.32 cm	23.6	25.3	23.5	60.9	59.6	62.0	24.6	26.6	23.2	46.6	46.0	50.0	3.8	2.1	2.1
Desinew 0.19 cm	27.3	23.6	25.8	60.0	60.7	60.3	23.8	22.4	21.0	64.2	48.9	52.9	2.2	1.5	1.4

	Insoluble Collagen			Total Collagen		
	CH	B	C	CH	B	C
Grind 0.32 cm	31.8	18.6	25.7	35.6	20.7	27.8
Desinew 0.19 cm	10.4	7.1	13.9	12.7	8.6	15.3

[a] Refer to footnote on table 14.

TABLE 16. Physcial measurements for patties from patties from bull, cutter and canner cow beef either ground or desinewed.

	% Diameter Change			% Height Change			% Cooking Loss			D of D[b]			Temperature °C		
	CH[a]	B	C	CH	B	C	CH	B	C	CH	B	C	CH	B	C
Grind 0.32 cm	20.9	22.5	22.0	23.8	12.9	20.7	43.7	40.6	41.7	2.0	2.1	2.4	72.8	75.1	67.1
Desinew 0.19 cm	23.2	22.2	22.8	30.9	22.9	21.8	48.8	41.8	43.1	2.1	2.0	2.0	71.3	73.5	68.2

	Total Work Instron			Instron Shear Force (Kg)		
	CH	B	C	CH	B	C
Grind 0.32 cm	31.4[c]	40.9[c]	52.3[c]	5.3	5.5	7.3
Desinew 0.19 cm	29.4[d]	39.1[d]	42.7[d]	4.2	5.8	7.1

[a] Refer to Footnote b in Table 14.

[b] Degree of doneness.

Figure 1a
Initial Tenderness Source x
Comparison 4 Interaction
$(P < 0.01)$.

Figure 1b
Final Tenderness Source x
Comparison 4 Interaction
$(P < 0.01)$.

Figure 1c
Total Shear Work Source x
Comparison 4 Interaction
$(P < 0.01)$.

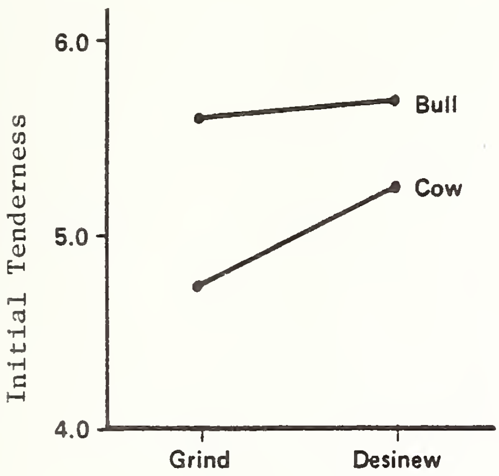

Figure 1a

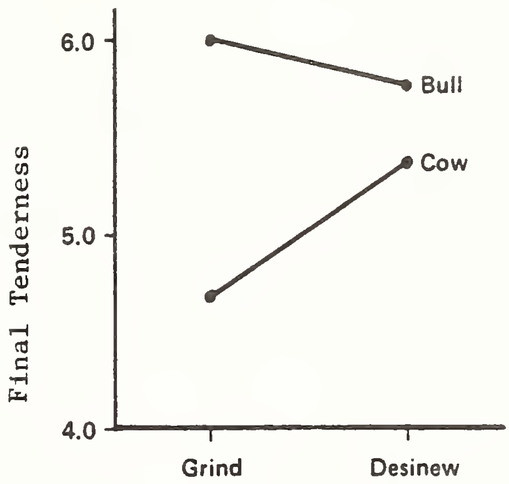

Figure 1b

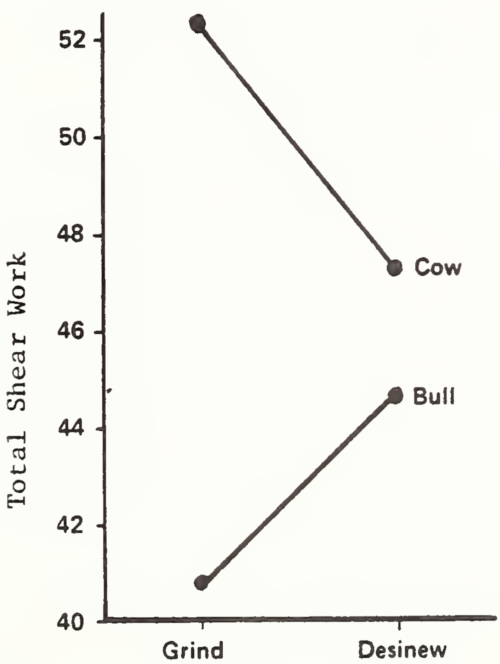

Figure 1c

Figure 2a
Total Shear Work Source x
Comparison 1 Interaction
($P < 0.01$).

Figure 2b
Shear Force (lb) Source x
Comparison 1 Interaction
($P < 0.01$).

Figure 2c
Shear Force Source x
Comparison 3 Interaction
($P < 0.01$).

Figure 2d
Total Shear Work Source x
Comparison 3 Interaction
($P < 0.01$).

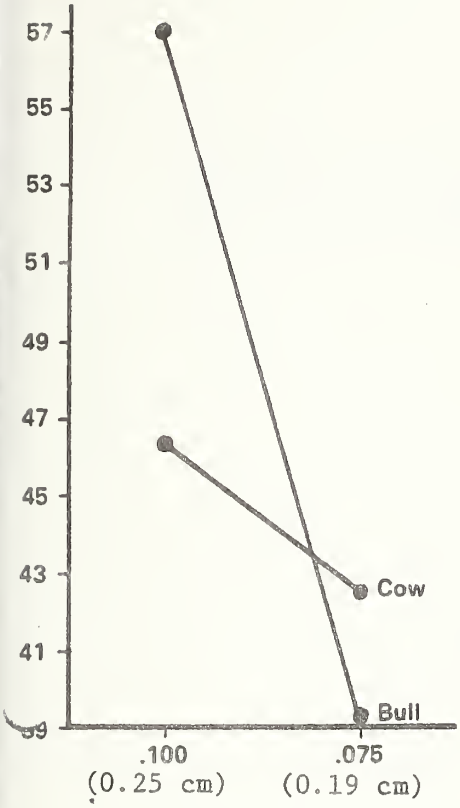

Figure 2a

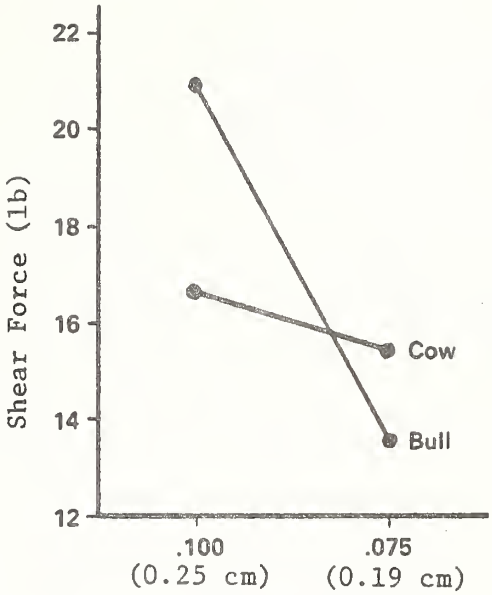

Figure 2b

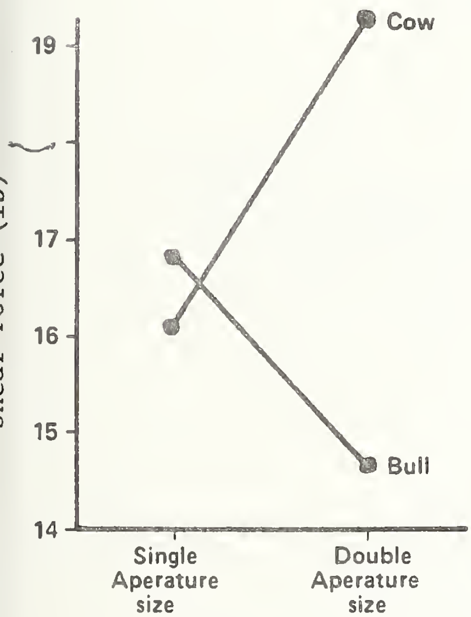

Figure 2c

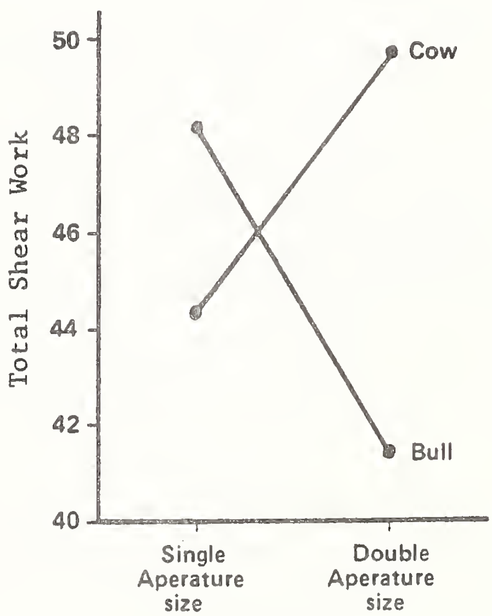

Figure 2d

Figure 3a
Initial Connective Tissue Amount
Source x Comparison 4 Interaction
($P < 0.01$).

Figure 3b
Final Connective Tissue Amount
Source x Comparison 4 Interaction ($P < 0.01$).

Figure 3c
Initial Connective Tissue Amount
Source x Comparison 1 Interaction
($P < 0.01$).

Figure 3d
Final Connective Tissue Amount
Source x Comparison 1 Interaction ($P < 0.01$).

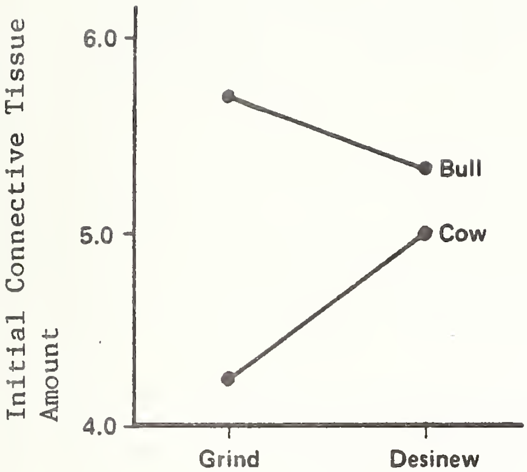

Figure 3a

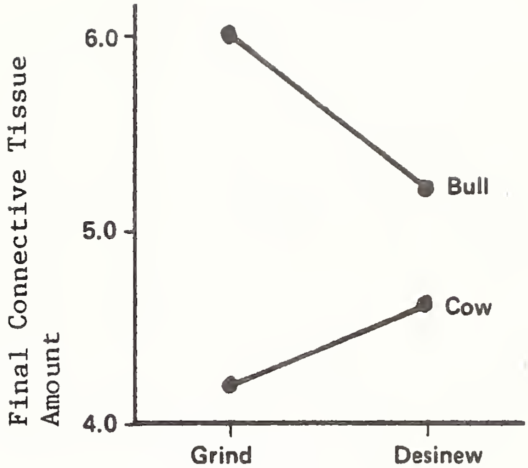

Figure 3b

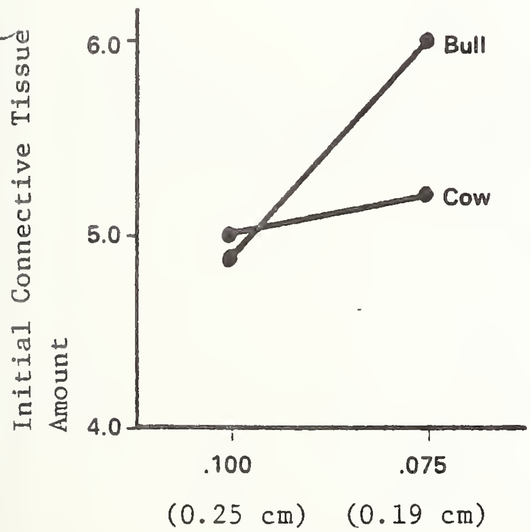

Figure 3c

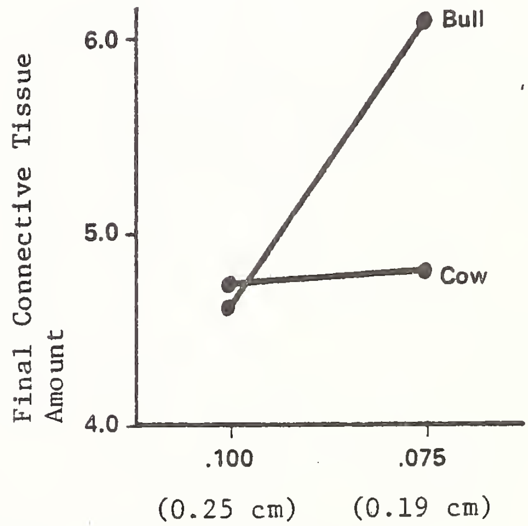

Figure 3d

Figure 4a
Soluble Collagen (mg/g) Source x Comparison 3 Interaction ($P < 0.01$).

Figure 4b
Insoluble Collagen (mg/g) Source x Comparison 2 Interaction ($P < 0.01$).

Figure 4c
Insoluble Collagen (mg/g) Source x Comparison 1 Interaction ($P < 0.01$).

Figure 4d
Total Collagen (mg/g) Source x Comparison 1 Interaction ($P < 0.01$).

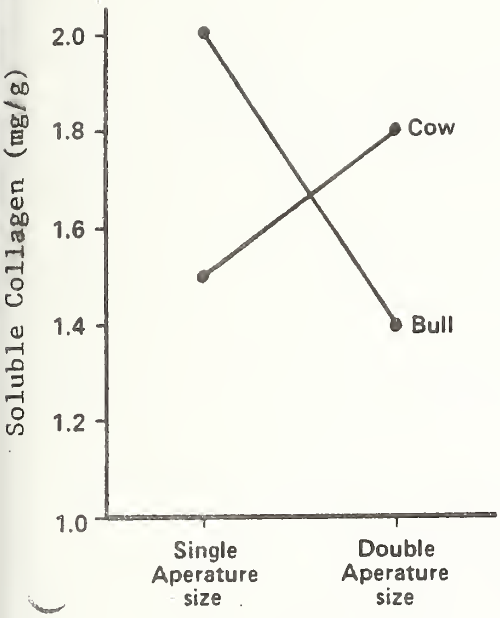

Figure 4a

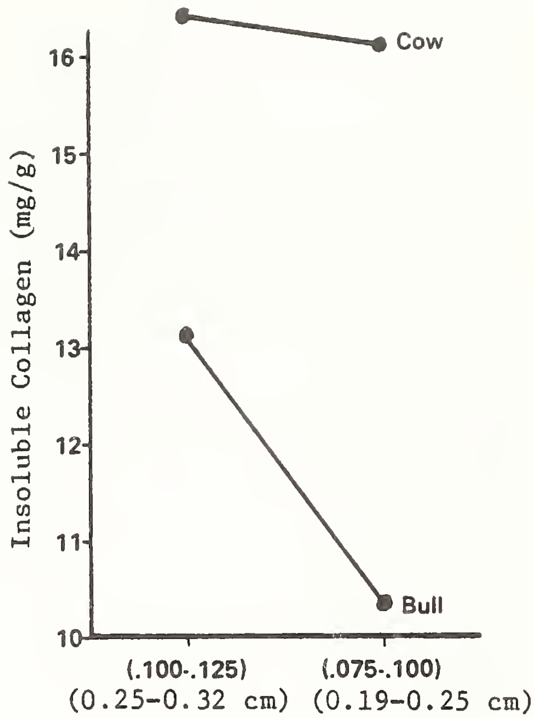

Figure 4b

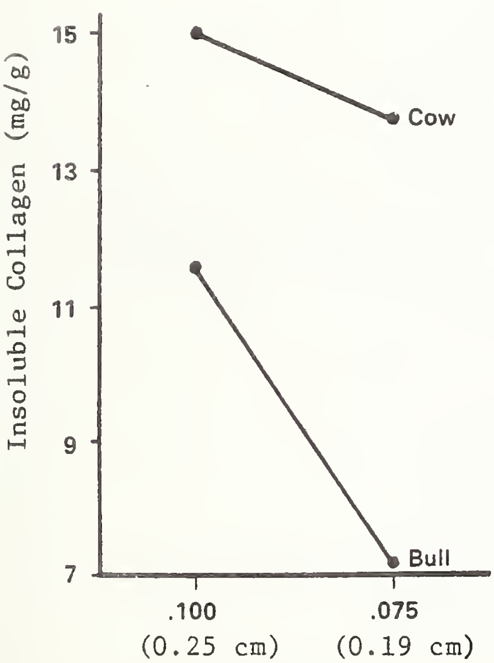

Figure 4c

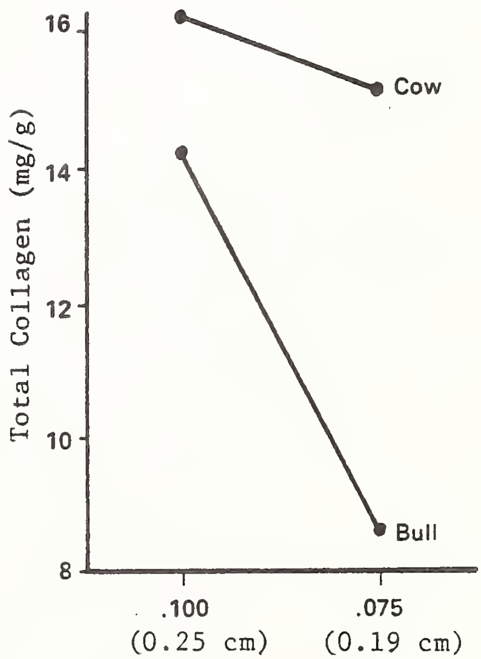

Figure 4d

Figure 5a
Insoluble Collagen (mg/g) Source x Comparison 4 Interaction ($P < 0.01$).

Figure 5b
Total Collagen (mg/g) Source x Comparison 4 Interaction ($P < 0.01$).

Figure 5c
% Height Change Source x Comparison 4 Interaction ($P < 0.01$).

Figure 5d
% Diameter Change Source x Comparison 3 Interaction ($P < 0.01$).

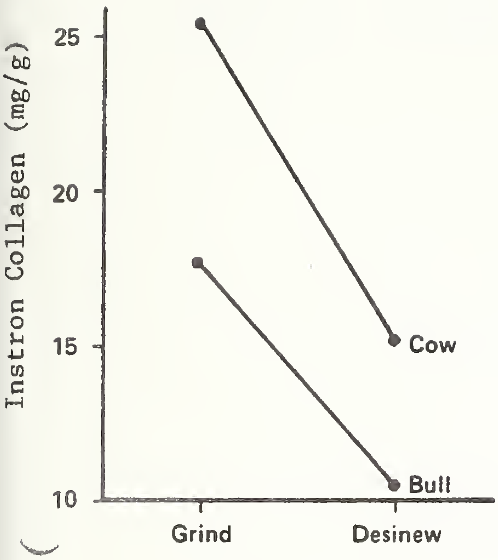

Figure 5a

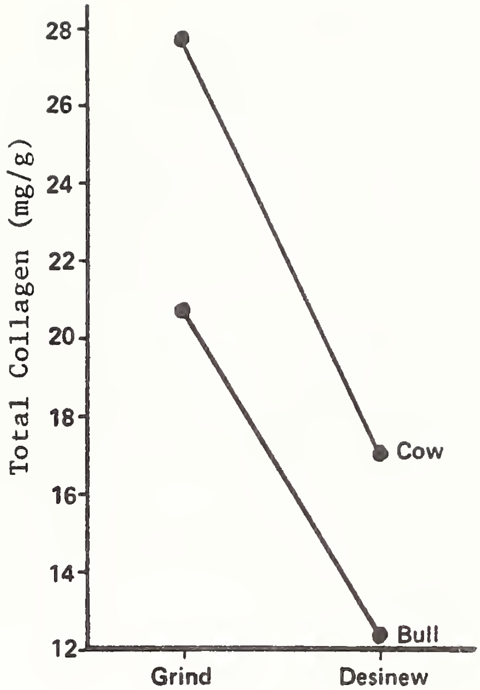

Figure 5b

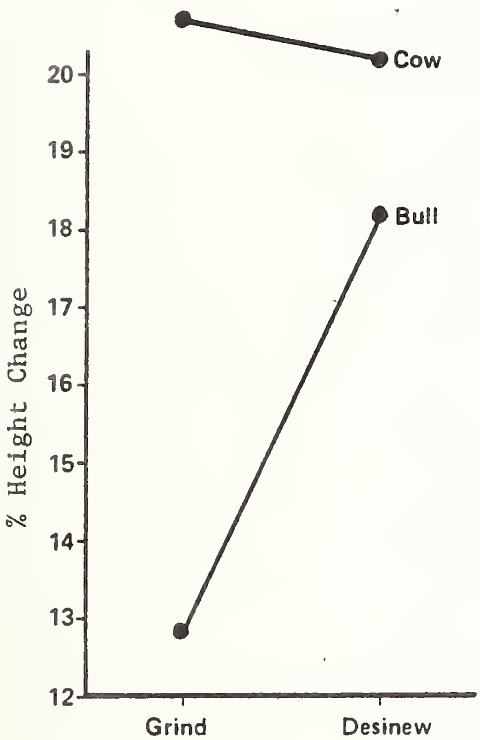

Figure 5c

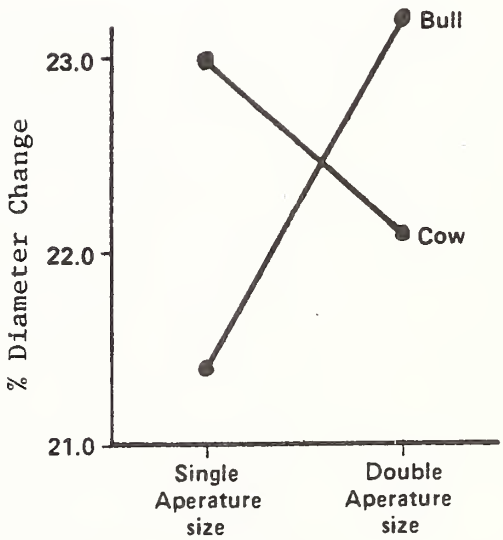

Figure 5d

Figure 6a
% Moisture in Cooked Patty Source x Comparison 1 Interaction ($P < 0.01$).

Figure 6b
% Moisture in Cooked Patty Source x Comparison 2 Interaction ($P < 0.01$).

Figure 6c
% Moisture in Cooked Patty Source x Comparison 3 Interaction ($P < 0.01$).

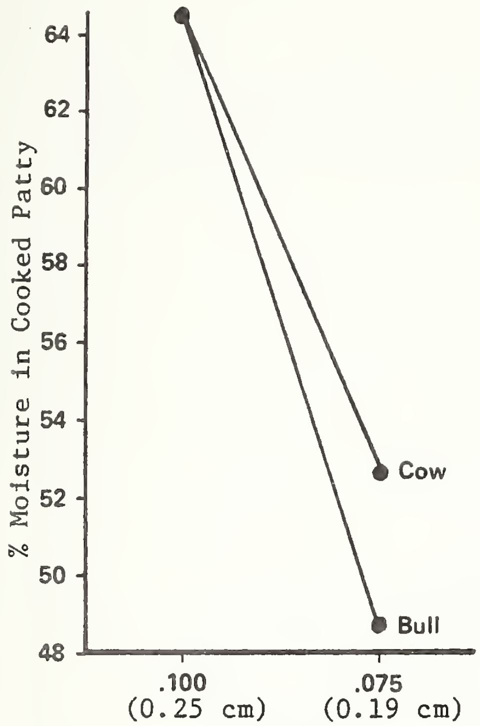

Figure 6a

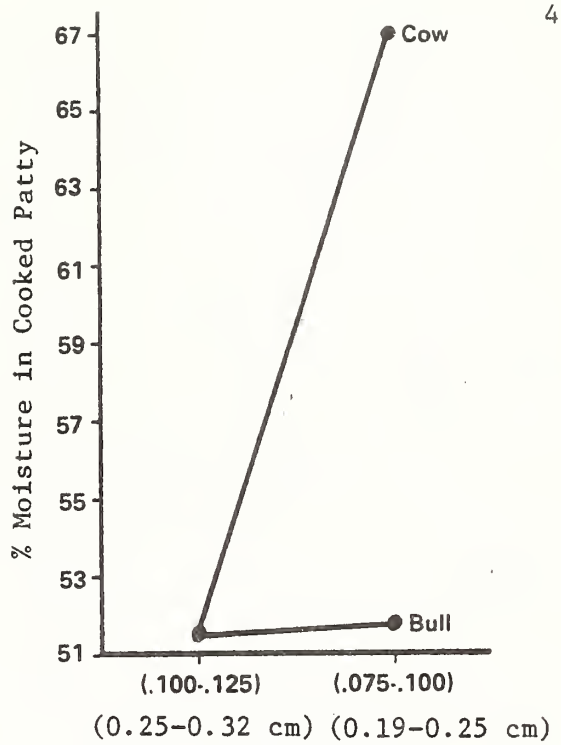

Figure 6b

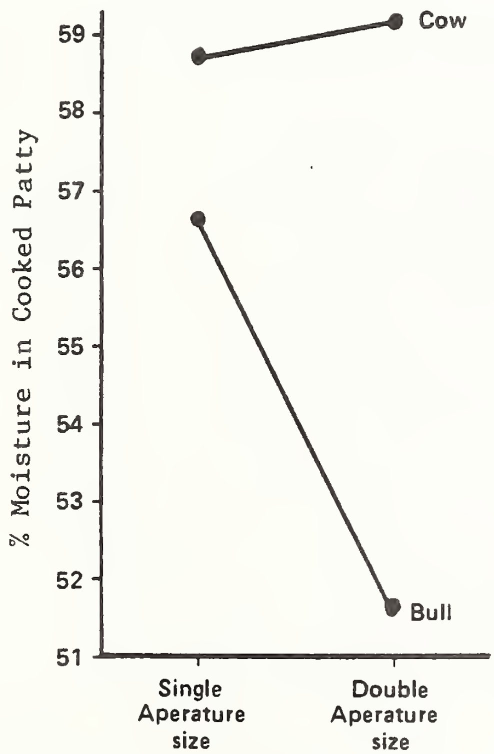

Figure 6c

Figure 7a
Initial Tenderness Source x Comparison 4 Interaction ($P < 0.01$).

Figure 7b
Source x Comparison 4 Interaction ($P < 0.01$).

Figure 7c
Instron Total Work Source x Comparison 4 Interaction ($P < 0.01$).

Figure 7d
Instron Shear Force (lb) Source x Comparison 3 Interaction ($P < 0.01$).

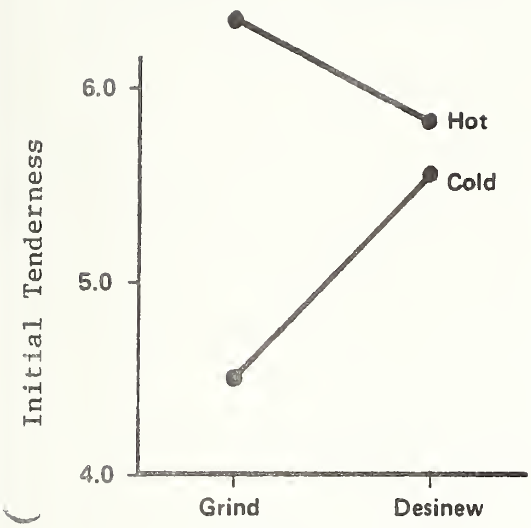

Figure 7a

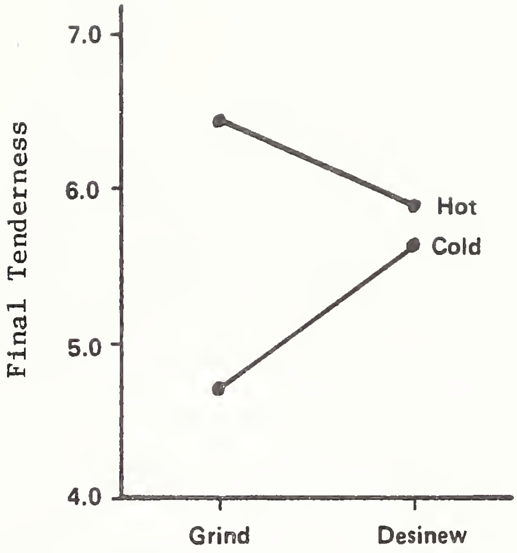

Figure 7b

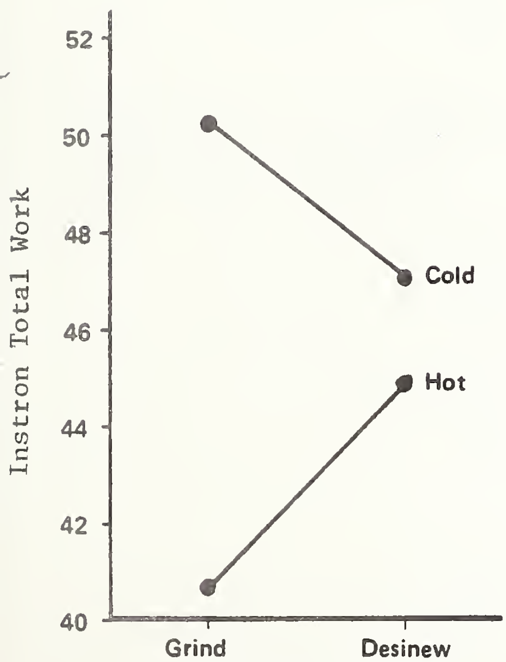

Figure 7c

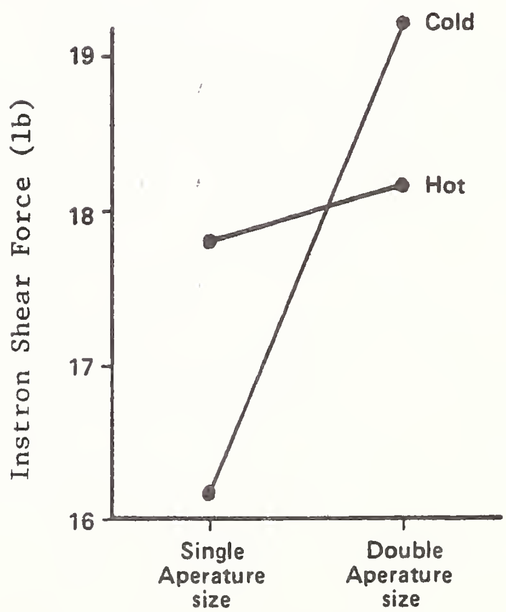

Figure 7d

Figure 8a
Instron Total Work Source x Comparison 2 Interaction ($P < 0.01$).

Figure 8b
Instron Shear Force (lb) Source x Comparison 2 Interaction ($P < 0.01$).

Figure 8c
Instron Total Work Source x Comparison 1 Interaction ($P < 0.01$).

Figure 8d
Instron Shear Force (lb) Source x Comparison 1 Interaction ($P < 0.01$).

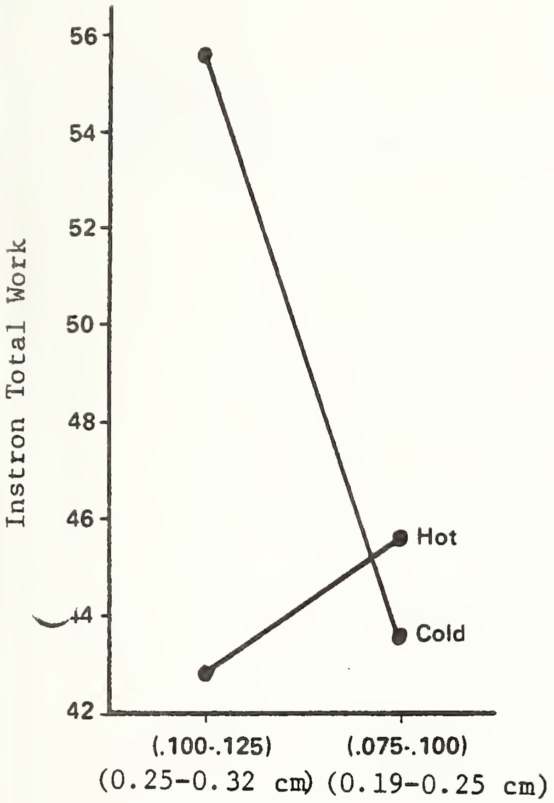

Figure 8a

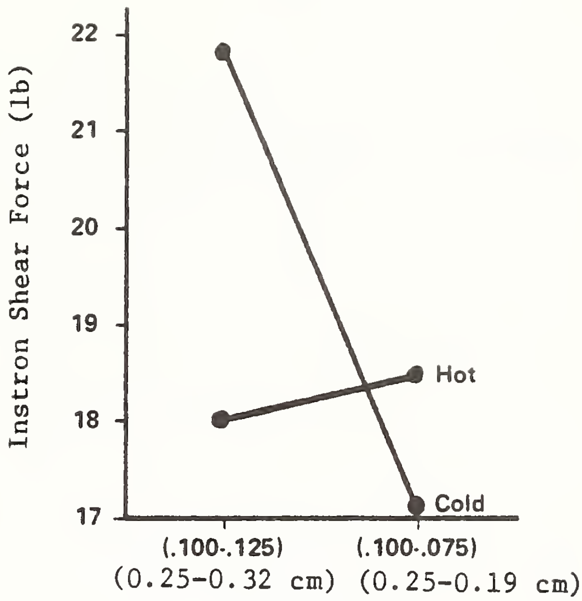

Figure 8b

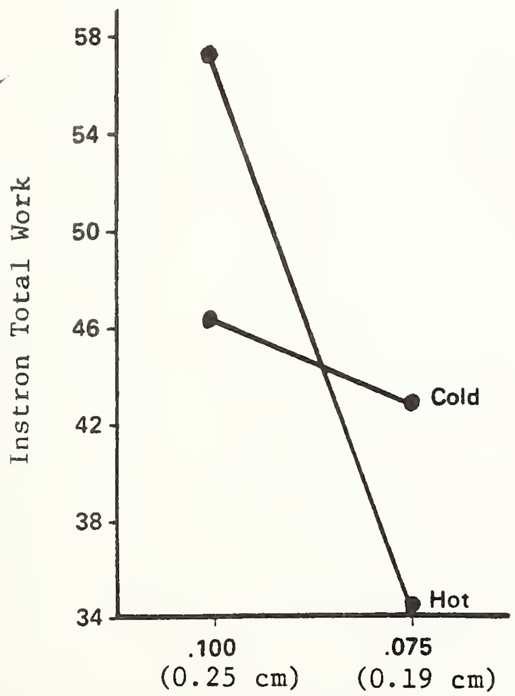

Figure 8c

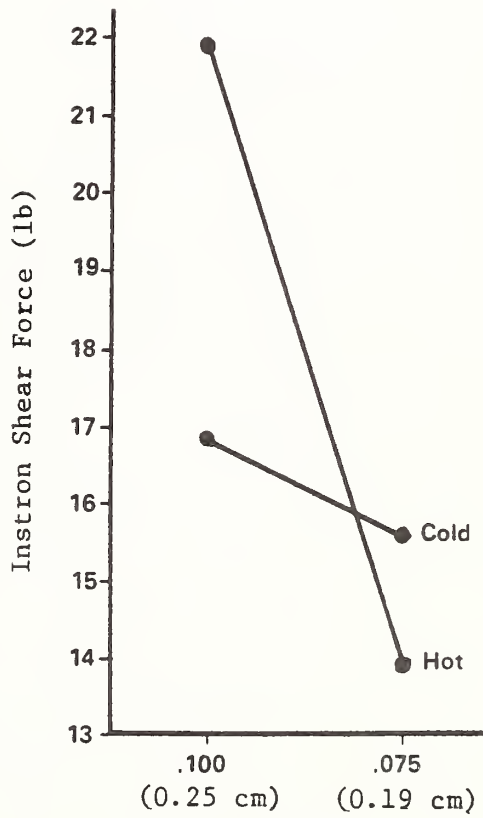

Figure 8d

Figure 9a
Initial Connective Tissue Amount
Source x Comparison 4 Interaction
($P < 0.01$).

Figure 9b
Initial Connective Tissue Amount
Source x Comparison 1 Interaction
($P < 0.01$).

Figure 9c
Final Connective Tissue Amount
Source x Comparison 1 Interaction ($P < 0.01$).

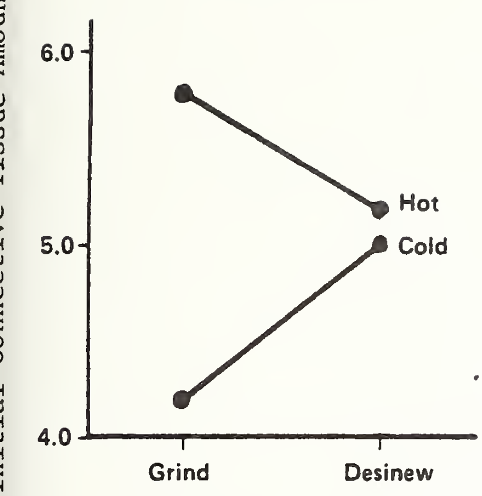

Figure 9a

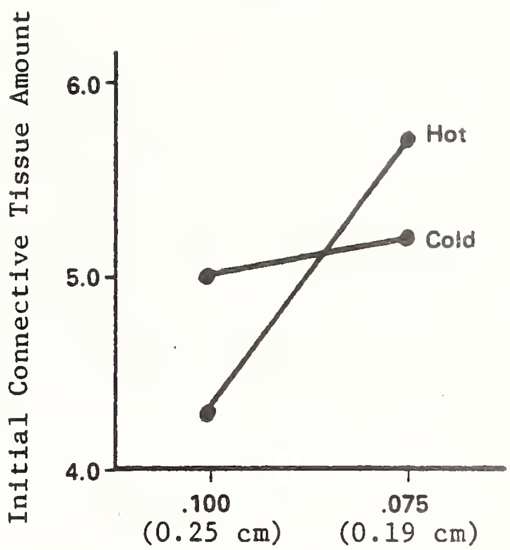

Figure 9b

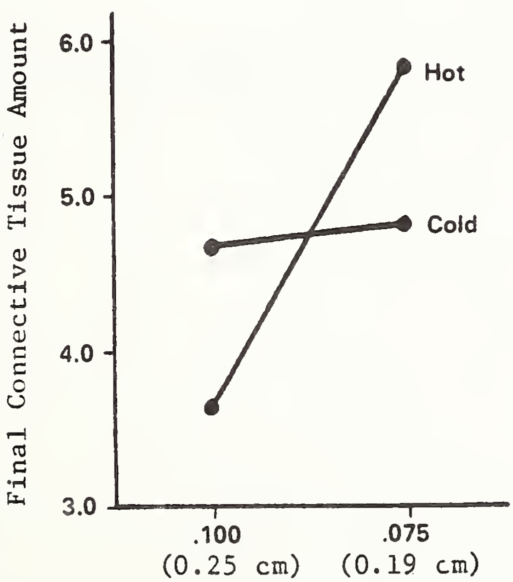

Figure 9c

Figure 10a
Insoluble Collagen (mg/g) Source x Comparison 4 Interaction ($P < 0.01$).

Figure 10b
Total Collagen (mg/g) Source x Comparison 4 Interaction ($P < 0.01$).

Figure 10c
Insoluble Collagen (mg/g) Source x Comparison 1 Interaction ($P < 0.01$).

Figure 10d
Total Collagen (mg/g) Source x Comparison 1 Interaction ($P < 0.01$).

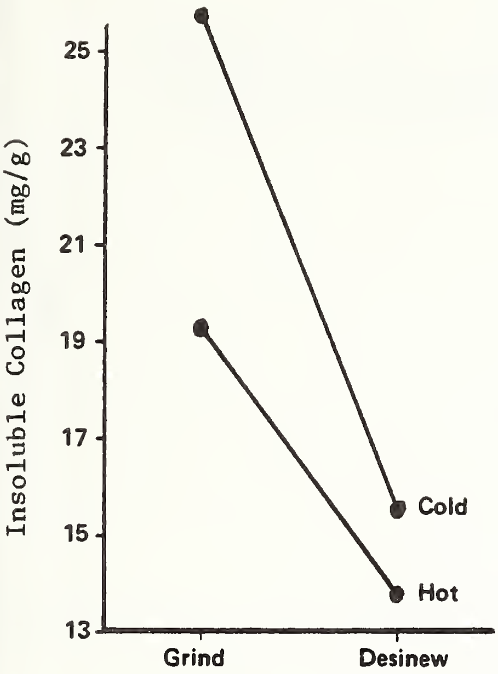

Figure 10a

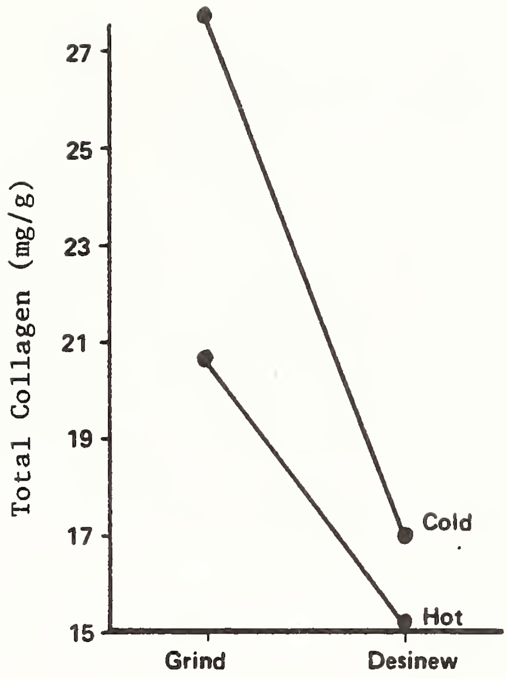

Figure 10b

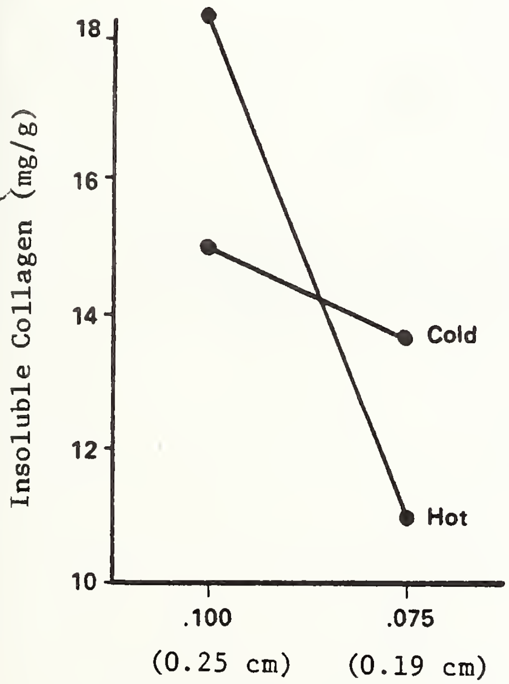

Figure 10c

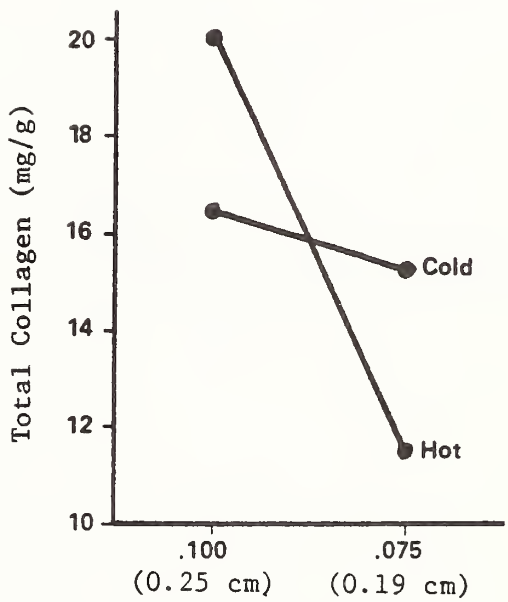

Figure 10d

Figure 11a
Insoluble Collagen (mg/g) Source
x Comparison 3 Interaction
($P < 0.01$).

Figure 11b
Total Collagen (mg/g) Source
x Comparison 3 Interaction
($P < 0.01$).

Figure 11c
% Moisture in Cooked Patty Source
x Comparison 1 Interaction
($P < 0.01$).

Figure 11d
% Moisture in Cooked Patty Source
x Comparison 2 Interaction
($P < 0.01$).

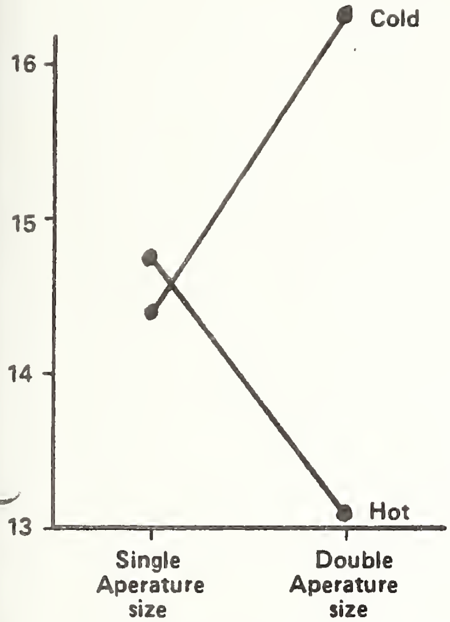

Figure 11a

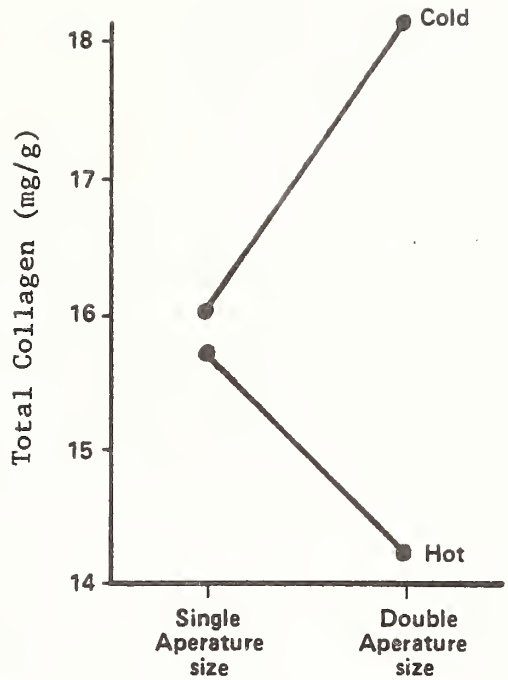

Figure 11b

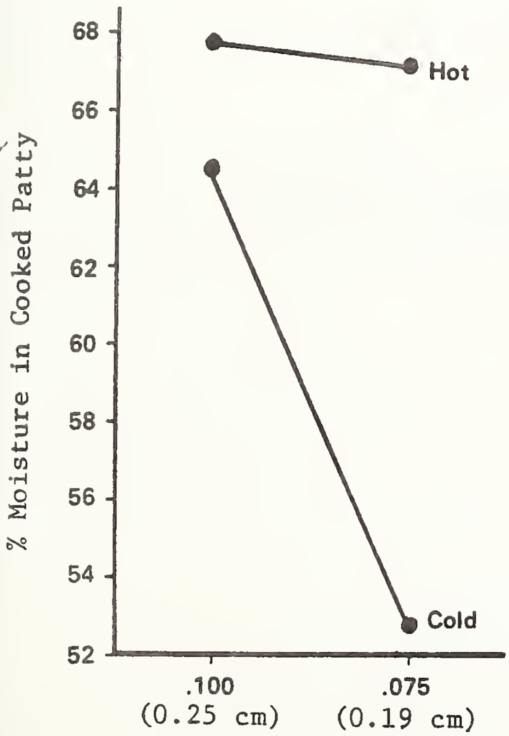

Figure 11c

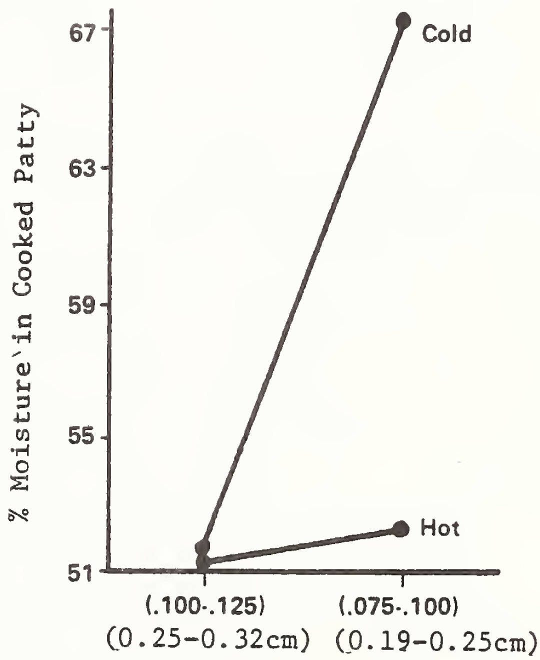

Figure 11d

Figure 12a
% Moisture in Cooked Patty Source x Comparison 3 Interaction (P < 0.01).

Figure 12b
% Cooking Loss Source x Compariso
Interaction (P < 0.01).

Figure 12c
Juiciness Source x Comparison 4 Interaction (P < 0.01).

Figure 12d
Ground Beef Flavor Intensity Source x Comparison 4 Interaction (P < 0.01).

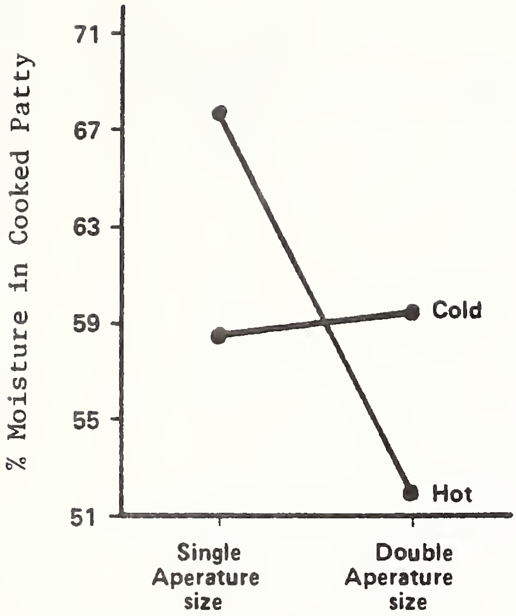

Figure 12a

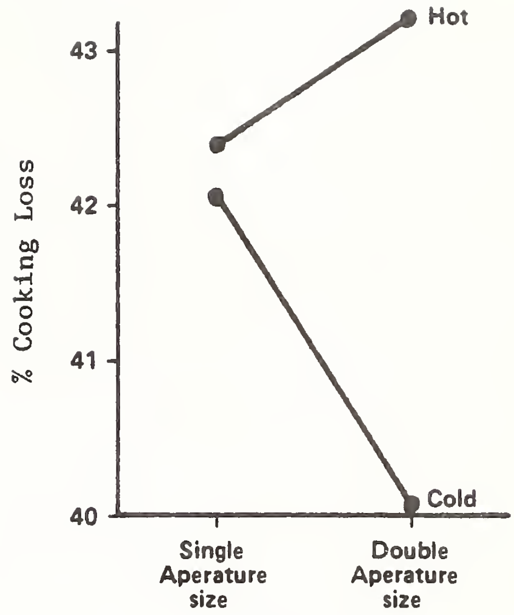

Figure 12b

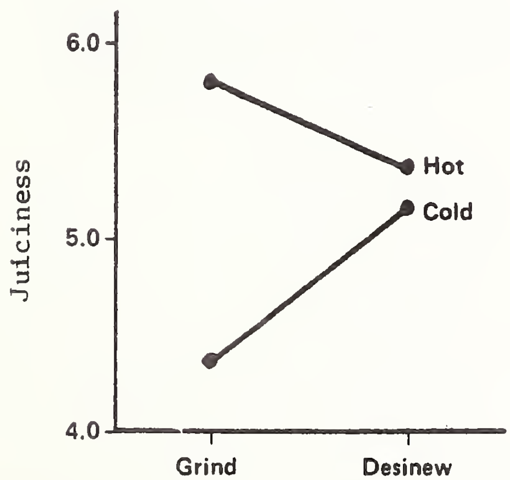

Figure 12c

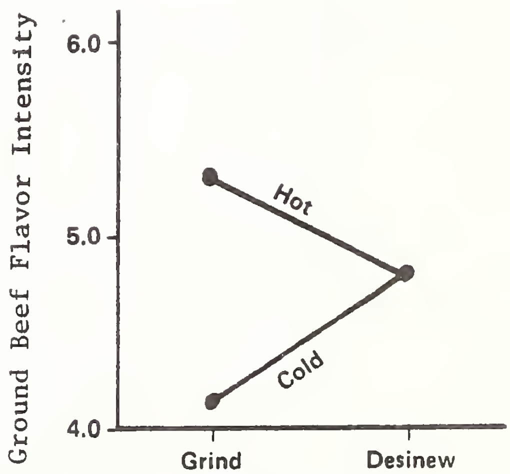

Figure 12d

Figure 13a
Initial Tenderness Comminution x Comparison S1 Interaction ($P < 0.01$).

Figure 13b
Final Tenderness Comminution x Comparison S1 Interaction ($P < 0.01$).

Figure 13c
Soluble Collagen (mg/g) Comminution x Comparison S2 Interaction ($P < 0.01$).

Figure 13d
Insoluble Collagen Comminution x Comparison S2 Interaction ($P < 0.01$).

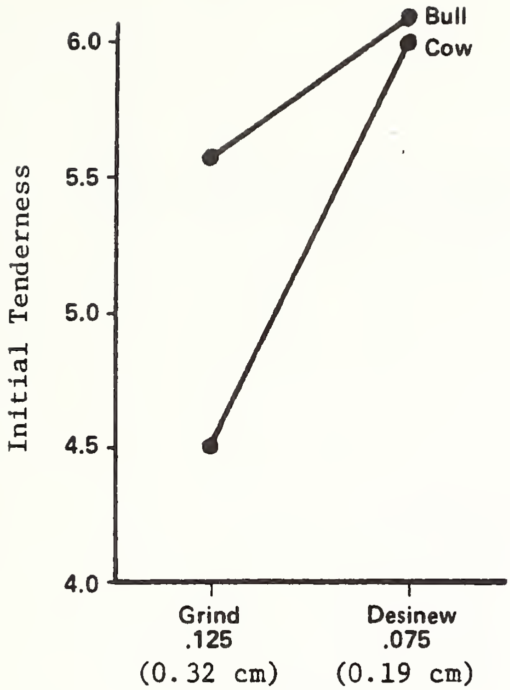

Figure 13a

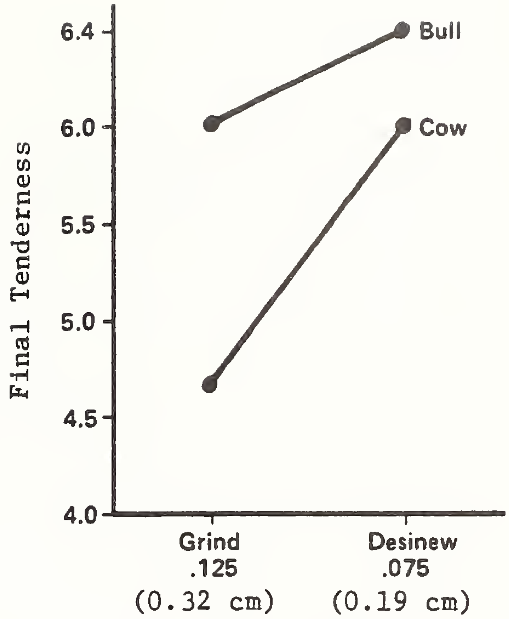

Figure 13b

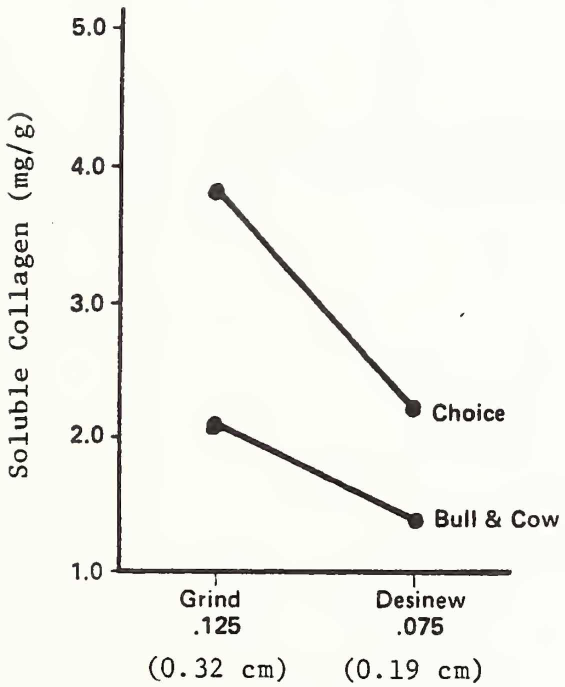

Figure 13c

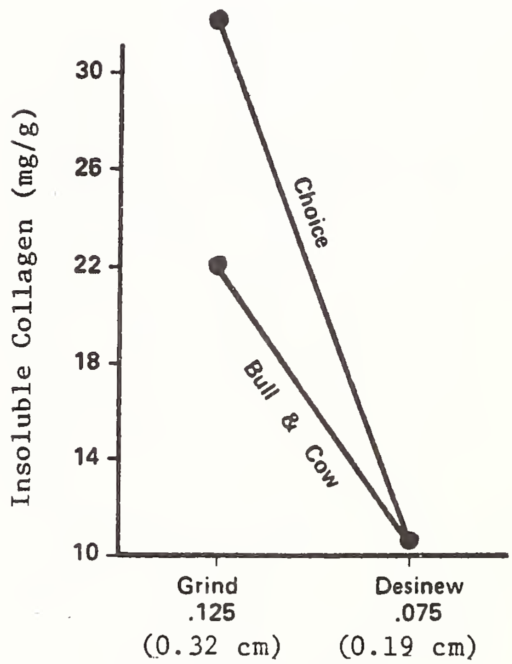

Figure 13d

Figure 14a
Total Collagen (mg/g) Comminution x Comparison S2 Interaction ($P < 0.01$).

Figure 14b
% Cooking Loss Comminution x Comparison S2 Interaction ($P < 0.01$).

Figure 14c
% Moisture in Cooked Patty Comminution x Comparison S2 Interaction ($P < 0.01$).

Figure 14d
% Height Change Comminution x Comparison S1 Interaction ($P < 0.01$).

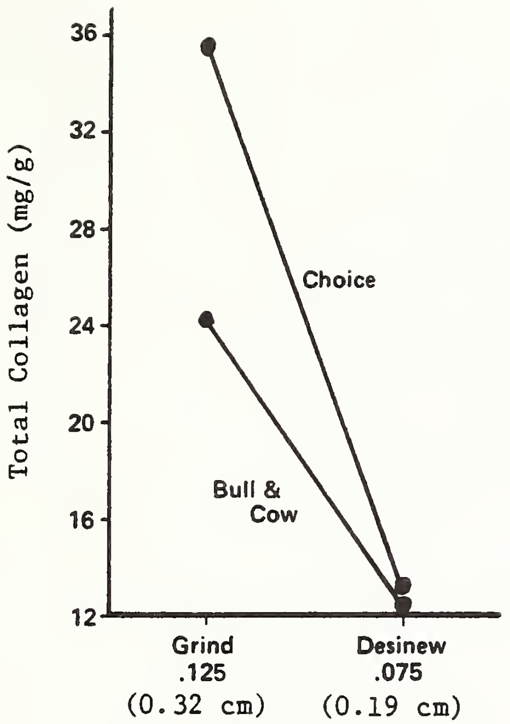

Figure 14a

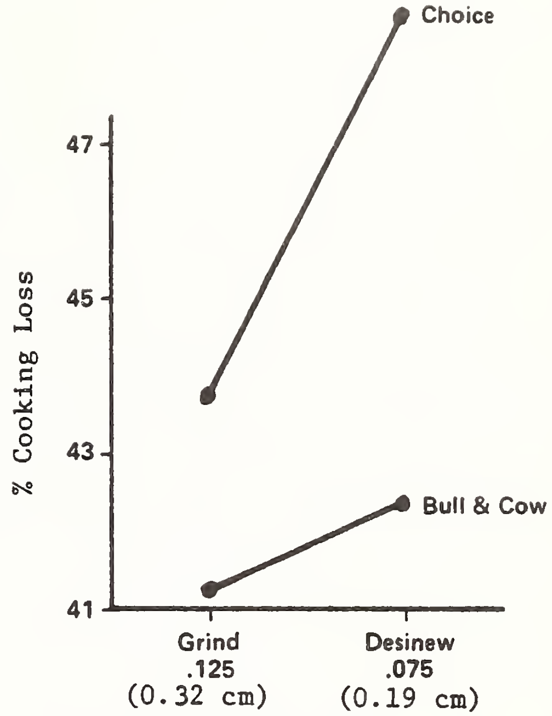

Figure 14b

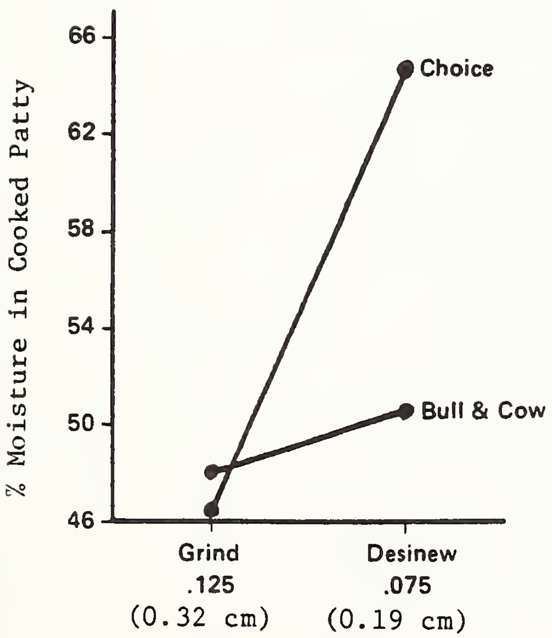

Figure 14c

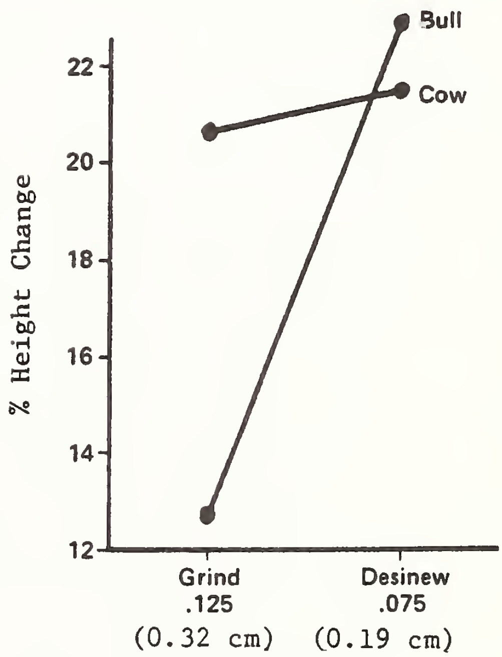

Figure 14d

Phase I - Part 2

Objective: To evaluate the effect on palatability and shelf-life of preparing ground beef from unchilled (hot) beef carcasses.

PHYSICAL, CHEMICAL & SENSORY PROPERTIES OF GROUND BEEF PREPARED FROM HOT AND CHILLED BEEF CARCASSES

Introduction

More than 40 million cattle and calves are being slaughtered in the U.S. each year. Vast amounts of energy are currently being used to process, transport and market this volume of meat. Alternate processing methods such as hot-boning offers tremendous possibilities in energy conservation and increased marketing efficiency. By the year 1980, about 50% of the beef slaughter will be consumed as ground beef (Pietraszek, 1975).

The ground beef industry represents a large proportion of the total energy requirements of the meat industry. Little, if any, data have been reported concerning the feasibility of producing ground beef from hot processed beef carcasses. Several potential problems of hot boning include textural changes, color differences and shelf-life. In order for the ground beef segment to be viable, the hot processing of steak and roast cuts from the same carcasses must also be possible. Much of the hot processing data in the literature have concentrated on the palatability of steaks and roasts from USDA Good and Choice carcasses (Kastner et al., 1973; Falk et al., 1975 and Schmidt and Gilbert, 1970). No data are reported on the effect of hot boning of mature (> 4 yrs) beef carcasses on shelf-life and palatability. The steak and roast cuts from these carcasses are usually tenderized by mechanical and enzymatic methods. This laboratory is currently investigating the effects of hot boning on the physical, chemical and microbial properties of ground

beef and steaks and roasts from mature beef carcasses. This manuscript will deal with the palatability and cookery yeilds of the ground beef segment of the study.

EXPERIMENTAL

Hot processed ground beef was prepared by three methods as outlined in Table 1. Each method contained two batches and each batch contained 4 sides of beef. Batch A was prepared in the a.m. and Batch B in the p.m. Opposite sides were assigned to the same batch for cold boning. Carcasses ranged in USDA quality grade from low to high utility and in maturity from "C" to "E" (> 4 yrs). The animals were slaughtered and the ground beef was prepared and stored at a commercial processing plant. One side of each carcass was hot-boned; the other half, cold-boned. At 3 hr postmortem, the top round, strip loin and ribeye cuts were removed from one side of each hot carcass and at 24 hr postmortem, the same muscles were removed from the sides which had been chilled at 2 to 3^{o}C and set aside for a different study. The remainder of the meat from the boned carcasses was used for ground beef fabrication in this study.

GRINDING METHODS - Chilled (control)

U.S. Choice plates (conventionally chilled) were added (approximately 30%) to the formulation in order to bring the final fat content to 21 $\pm$ 2%. The cow lean and choice plates were passed through a 1.27 cm plate, mechanically mixed for 3 min and ground through a 0.32 cm plate for the final grind. The average batch size was 360 to 400 kg. The control formulation was not actually a "control" because the grinding system was not identical

to those used for hot meat. The purpose of the experiment was to compare new systems that might work for hot meat with the most common system used for chilled meat.

METHOD 1 - Hot Processed

U.S. Choice plates (2 to 3°C) were added (approximately 30% of the formulation) to the formulation in order to bring the final fat content to 21 ± 2%. The hot lean and chilled beef plates were passed through a large kidney plate (1.27cm x 1.90cm) and mixed for 3 to 4 min. During mixing, CO_2 snow was added at a 1:10 ratio of CO_2 to beef. Following the mix, the product was ground through a 0.32 cm plate for the final grind.

METHOD 2 - Hot Processed

Method 2 differed from method 1 only in the number of grinds and the manner in which the CO_2 snow was added. The lean and fat was passed through a kidney plate, mixed 3 to 4 min; passed through a 1.27 cm plate, mixed 3 to 4 min and passed through a 0.32 cm plate for the final grind. The CO_2 snow was added at a ratio of 1:10 with two-thirds added during the first and one-third during the second mix.

METHOD 3 - Hot Processed

Method 3 differed from method 2 only in the amount of CO_2 snow added and the absence of choice plates. Since no chilled choice plates were added the ratio of CO_2 snow to meat was increased to 1.5:10. Also the carcasses used for this method were slightly fatter than those used in methods 1 and 2 in order for the final fat content to be 21 ± 2%.

PATTIES

Ground beef from all formulations were formed into 113 g (4 oz) patties using a FORMAX model 26 patty machine. Patties were stacked (10 per stack)

boxed and frozen in a blast freezer and stored at -10°C for 5 days before shipment to Beltsville, Md. for analysis.

TRAINED PANEL

A 10-member descriptive attribute panel, trained by the procedures of Cross et al. (1978a) and AMSA (1978), evaluated samples from each treatment in a total of 10 sessions. Six samples were evaluated per session and each treatment was replicated 5 times. The panel rated each sample for differences in tenderness, juiciness, connective tissue amount and ground beef flavor intensity with 8= extremely tender, juicy, no detectable connective tissue, and intense and 1= extremely tough, dry, abundant connective tissue and bland in ground beef flavor.

COOKERY AND PRESENTATION TO PANEL

Frozen patties were broiled on electric Farberware grills (model 450-A) to an approximate internal temperature of 60°C. Temperature was monitored during cooking with teflon-coated iron/constantan thermocouples. Beef patties prepared from hot-boned beef carcasses required 11 minutes total cooking time while the control patties required 13 min. Frozen and cooked weights were obtained in order to calculate total cooking losses. Four patties were prepared for each session. Each patty was sectioned into 6 pieces and two of the 24 pieces (4 patties) were randomly assigned to each panelist. The samples were served as warm as possible to the panelist as described in ASMA (1978). After sectioning, the pieces were pictorially scored for degree of doneness (color photographs with 1= well done and 8= rate) by a trained laboratory technician.

SHEAR FORCE

Ten patties from each method/batch group were used for determination of Instron shear force according to the single-blade procedure outlined by Cross

et al. (1978b). Four 2.54 cm squares were obtained from each patty, thus each mean value for method/batch represents 40 observations.

PHYSICAL AND CHEMICAL

Height and diameter measurements were obtained on the ten frozen and cooked patties used for the Instron. Percent fat and moisture was determined on raw and cooked patties according to AOAC procedures. A pH determination was made on ten frozen, thawed and cooked patties from each treatment using the procedure described by Nichols and Cross (1978).

RESULTS AND DISCUSSION

Data in Tables 2-4 combines methods of processing to allow a direct comparison of sensory, physical and chemical properties of ground beef prepared from hot versus chilled beef. Mean palatability and shear force values are presented in Table 2. Ground beef patties prepared from hot processed beef were significantly ($P < .05$) more tender (panel) and juicy than patties prepared from chilled beef. Differences in shear force were not evident although the trends were similar to those established by the trained panel. As might be expected, treatment had no significant effects on amount of connective tissue or flavor intensity.

Total cooking loss was significantly less in the hot processed patties when compared to the chilled patties (Table 3). The differences were quite large (33.85 vs 41.06%) and of considerable practical importance. These differences in cooking losses were reflected in ratings for juiciness (Table 2). Hot processed patties had significantly less configuration change and diameter than chilled patties. Percent change in height and thaw loss was not significantly affected by treatment. In an institutional-use situation,

the most important configuration parameter would be diameter in order to keep a constant area of the bun covered.

Since the hot-boned beef was processed prerigor, the possibility existed for some thaw rigor to occur. In this study the possibility was small because the patties were frozen over a 10-20 hr period. Muscle pH was determined on the frozen, thawed and cooked samples to determine if the sample had reached its ultimate pH prior to freezing. This data is presented in Table 4. As expected, there were no significant differences in pH between hot and chilled patties. This is also reflected in the lack of significant differences in thaw loss (Table 3). If the hot processed patties had been frozen cryogenically thaw rigor might have been a problem. Research is in progress to investigate these possibilities. Percent fat and water did not differ significantly in the raw patty (Table 4) and percent fat was not different in the cooked patty. Percent moisture differed significantly in the hot and chilled cooked patty. This, of course, was illustrated in the differences in cooking loss (Table 3). One might expect that a patty from hot processed beef might contain more moisture in the raw as well as the cooked state. If this were the case, one could expect less nutrients from a certain size hot processed patty. Such was not the case, as shown by the data in Table 4. Undoubtedly, the hot and chilled patties were quite similar as to composition in the raw state but the chilled patty loses more water during cooking. This water results in lower juiciness and tenderness ratings and could possibly mean more patty left on the plate.

An evaluation of the effect of method of grinding on sensory, physical and chemical properties is presented in Table 5 and 6. Data for sensory and shear is outlined in Table 5. Method of grinding had no significant

affect on any palatability trait except flavor intensity. Patties prepared by Method 3 were less intense in flavor than Methods 1 and 2. This difference was probably a reflection of the absence of choice plates in the formulation rather than method of grinding. In any case, the difference was probably too small to be of practical importance. It is interesting to note that patties prepared from hot boned beef were more tender and juicy than patties prepared from chilled beef regardless of method of grinding.

Percent total cooking loss, height change, thaw loss and degree of doneness was not significantly affected by method of grinding (Table 6). Percent diameter change was greatest in patties prepared by Method 1 (Kidney plate x 0.32 cm). It is difficult to explain why the double grind should result in more diameter shrinkage than the triple grinds. A possible explanation could be the effect of the increased back pressure in the double versus the triple grind systems. Mean pH values of frozen, and thawed and cooked patties; and raw and cooked fat and water percentages were not significantly affected by method of grinding (data not presented).

It is quite evident from these data that beef patties can be prepared from hot processed beef that are equal to or superior to patties prepared from conventionally chilled beef in palatability, physical and chemical properties. Patties prepared from hot processed beef were significantly more tender and juicy and lost less water during cooking.

TABLE 1. Design

PREPARATION METHODS[a]							
1 (Hot) Batch		2 (Hot) Batch		3 (Hot) Batch		Control (Chill) Batch	
A	B	A	B	A	B	A	B
N= 4 sides per batch							

[a]Method 1: Kidney plate x 0.32 cm final.

Method 2: Kidney plate x 1.27 cm x 0.32 final.

Method 3: No choice plates; Kidney plate x 1.27 cm x 0.32 final.

Control: 1.27 cm x 0.32 cm final.

TABLE 2. Mean palatability and shear force values for cooked ground beef prepared from hot and chilled muscle.

	TYPE OF PROCESSING	
TRAIT	HOT	CHILLED
Tenderness[a]	5.69[e]	5.22[f]
Connective Tissue[b]	4.26[e]	4.38[e]
Juiciness[c]	5.47[e]	4.75[f]
Flavor Intensity[d]	5.23[e]	5.27[e]
Max Shear Force, kg.	10.99[e]	11.96[e]

[a]8 = extremely tender and 1 = extremely tough.

[b]8 = none and 1 = abundant amount.

[c]8 = extremely juicy and 1 = extremely dry.

[d]8 = extremely intense and 1 = extremely bland.

n = 30 observations per mean.

[ef] means in the same row with different superscripts are significantly different ($P < .05$).

TABLE 3. Cooking properties of ground beef patties prepared from hot and chilled muscle.

	TYPE OF PROCESSING	
TRAIT	HOT	CHILLED
Total Cooking Loss, %	33.85[b]	41.06[c]
Degree of Doneness[a]	2.32[b]	2.45[b]
Diameter Change, %	14.93[b]	19.32[c]
Height Change, %	16.06[b]	14.04[b]
Thaw Loss, %	5.39[b]	6.21[b]

[a]8 = rate and 1 = well done

[bc] means in the same row with different superscripts are significantly different ($P < .05$).

TABLE 4. Chemical properties of ground beef prepared from hot and chilled muscle.

	TYPE OF PROCESSING	
TRAIT	HOT	CHILLED
pH raw, frozen	5.52[a]	5.46[a]
pH raw, thawed	5.37[a]	5.32[a]
pH cooked	5.50[a]	5.46[a]
H_2O, raw, %	62.11[a]	62.29[a]
fat, raw, %	20.01[a]	19.55[a]
H_2O, cooked, %	52.10[a]	48.60[b]
fat, cooked, %	21.10[a]	21.80[a]

[ab] means in the same row with different superscripts are significantly different ($P < .05$).

TABLE 5. Comparison of palatability traits of three systems of grinding hot, processed beef.

TRAIT	HOT PROCESSED BEEF METHOD OF GRINDING[a] 1	2	3	Control Chilled
Tenderness[b]	5.48^{f}	5.90^{f}	5.68^{f}	5.22
Connective Tissue[c]	4.06^{f}	4.48^{f}	4.24^{f}	4.38
Juiciness[d]	5.36^{f}	5.61^{f}	5.43^{f}	4.75
Flavor Intensity[e]	5.39^{f}	5.37^{f}	4.93^{g}	5.27
Max. Shear Force, kg.	11.19^{f}	10.35^{f}	11.38^{f}	11.96

[a]1 = kidney plate x 0.32 cm plate.
2 = kidney plate x 1.27 cm plate + 0.32 cm plate.
3 = kidney plate x 1.27 cm plate + 0.32 cm plate (no Choice plates added as in 1 and 2).

[b]8 = extremely tender and 1 = extremely tough.

[c]8 = none and 1 = abundant amount.

[d]8 = extremely juicy and 1 = extremely dry.

[e]8 = extremely intense and 1 = extremely bland.

[fg] means in the same row with different superscripts are significantly different ($P < .05$).

TABLE 6. Comparison of cooking properties of three systems of grinding hot beef.

	HOT PROCESSED BEEF METHOD OF GRINDING[a]			Control Chilled
TRAIT	1	2	3	
Total Cooking Loss, %	36.48[c]	35.04[c]	30.02[c]	41.06
Degree of Doneness[b]	2.05[c]	2.60[c]	2.30[c]	2.45
Diameter Change, %	16.53[c]	14.17[d]	14.08[d]	19.32
Height Change, %	18.24[c]	20.76[c]	9.17[c]	14.04
Thaw Loss, %	5.47[c]	6.23[c]	4.48[c]	6.21

[b] 8 = rare and 1 = well done.

[cd] means in the same row with different superscripts are significantly different ($P < .05$).

BACTERIOLOGICAL QUALITY OF GROUND BEEF PREPARED FROM HOT & CHILLED BEEF CARCASSES

Introduction

Fabrication of beef carcasses before they are chilled ("hot" boning) could have several advantages as an alternative to conventional beef fabrication. Removal of excess fat and bone prior to chilling could save considerable energy in terms of total refrigeration. Additional advantages could include savings in costs of transportation, labor, and investment. In recent years researchers investigated the characteristics of hot-boned bovine muscle (1, 3, 5-10, 12). Most of these studies were concerned with the effect of hot boning on tenderness and eating quality of meat from Good and Choice grade beef carcasses.

The fabrication of ground beef utilizes a large proportion of the bovine carcass. Few, if any, data have been reported about the feasibility of producing ground beef from hot-boned beef carcasses. Such ground beef might have potential problems, which include textural changes, color differences and shelf-life, and inordinate bacterial counts would be prohibitive. We compared the bacteriological quality and shelf-life of ground beef prepared from hot- and cold-boned beef carcasses.

EXPERIMENTAL

PRODUCT FABRICATION

Four USDA Utility grade beef carcasses were used in this investigation. The animals were slaughtered and the ground beef was prepared and stored at

a commercial beef slaughter and further processing plant. At 2 hr postmortem, the top round, strip loin and ribeye cuts were removed from one side of each carcass. At 24 hr postmortem, the comparable muscles were removed from the sides that had been chilled at 3 C. The remainder of the meat from the boned carcasses was used immediately (2 and 24 hr postmortem) for the ground beef fabrication.

The hot-boned meat was chilled by addition of CO_2 snow (0.1 kg CO_2/kg meat) during ground beef fabrication. The hot-boned meat from the four sides (about 450 kg) was ground through a kidney plate. Two-thirds of the CO_2 snow was added, and the coarsely ground meat was mixed 3 min. The meat was then ground through a 1.27 cm plate, the remainder of the CO_2 snow was added, and the meat was mixed again for 3 min. The final grind was through a 0.32 cm plate, after which the ground beef was packaged in oxygen-impermeable polyethylene casings to make 5-lb chub packs. The ground beef from the four chilled sides was prepared in the same manner except that CO_2 snow was not used. Fat content of the ground beef was about 21 percent.

Forty-eight ground beef chub packs from the hot-boned batch and 48 from the cold-boned batch were stored at 0 C. Three chub packs from each batch were transported (45 min) to the laboratory for bacteriological analyses after 0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39, 42, and 45 days of storage.

BACTERIOLOGICAL ANALYSES

Three locations within each chub pack were sampled aseptically to obtain a 25-g sample that was blended 2 min in 225 ml of sterile Butterfield's phosphate diluent (11). Serial dilutions of the samples were plated in duplicate on 3 sets of plate count agar (Difco Laboratories, Detroit, MI) plates.

Aerobic plate counts (APCs) were determined after the duplicate sets of plates were incubated 7 days at 5 C, 3 days at 20 C or 2 days at 35 C.

Most Probable Numbers (MPNs) of coliforms and Escherichia coli were determined by methods described in the Bacteriological Analytical Manual for Foods (4). All EC broth (Baltimore Biological Laboratory, Cockeysville, MD) tubes showing gas after 24 or 48 hr at 45.5 C were streaked onto Levine eosin methylene blue agar (BBL) for detection of typical E. coli colonies.

The logarithms (base 10) of the bacterial counts were treated statistically by analysis of variance (ANOVA) and Duncan's (2) multiple range test.

RESULTS AND DISCUSSION

There were no significant differences in initial APCs (5, 20, or 35 C) between the ground beef prepared from hot-boned and that prepared from cold-boned carcasses (Table 1). With one exception (APC 5 C at 3 days' storage) during the 45-day study, the APCs (5, 20, and 35 C) in ground beef from hot-boned were either significantly lower or not significantly different from APCs in ground beef from cold-boned carcasses.

The bacterial counts of the hot-boned ground beef did not increase as rapidly during storage as those of cold-boned. In hot-boned ground beef, APCs at 5 and 20 C did not increase significantly from 0-day counts until day 30 of storage at 0 C; APCs at 35 C were significantly higher than 0-day counts after 33 days. In ground beef from chilled carcasses, APCs at 5, 20, and 35 C were significantly higher than 0-day counts after 18, 21, and 24 days of storage, respectively.

After 45 days of storage, there were no significant differences in APCs (5, 20, or 35 C) between hot- and cold-boned ground beef, but the APCs were

slightly lower in the hot. Both products had reached the end of their microbiological shelf-life. During 45 days of storage, the APCs at 5, 20, and 35 C increased 2.55, 1.78, and 1.65 logs/g, respectively, in the hot-boned ground beef, and 3.08, 2.04, and 1.70 logs/g, respectively, in the cold-boned ground beef. The appearance and odor of both hot- and cold-boned ground beef were acceptable through 42 days of storage, but a slight off-odor was detected at 45 days.

MPNs of coliforms and _E. coli_ were very low initially and throughout the 45-day storage study (Table 2). There were no significant differences of any practical importance in numbers of these bacteria between hot- and cold-boned ground beef.

Our data indicate that ground beef prepared from hot-boned carcasses as described above has bacteriological quality and shelf-life that are equal to or better than those of ground beef prepared from chilled carcasses. As an alternate processing method, fabrication of ground beef from hot-boned carcasses offer the meat industry great potential for energy conservation.

TABLE 1. Effect of storage at 0 C on APCs in ground beef prepared from "hot" and chilled beef carcasses.

Days of Storage	APC (5 C)		APC (20 C)		APC (35 C)	
	Hot	Chilled	Hot	Chilled	Hot	Chilled
0	4.30kl[a]	3.94lm	5.05g-j	4.96hij	5.13g	5.13g
3	4.17l	3.44m	5.06g-j	4.89ij	5.06g	4.99g
6	4.01lm	3.98lm	5.15g-j	5.06g-j	5.11g	5.18g
9	3.95lm	4.35kl	4.90ij	4.96hij	5.01g	5.22fg
12	4.06l	4.50jkl	5.09g-j	4.92ij	5.27fg	4.99g
15	4.14l	4.47jkl	5.04g-j	4.79j	5.04g	4.92g
18	4.04lm	4.81jk	5.14g-j	5.17ghi	5.19g	5.07g
21	4.27kl	5.06hij	4.78j	5.36fg	4.93g	5.34fg
24	4.06l	5.94d-g	5.01g-j	6.17e	4.99g	5.97de
27	4.26kl	6.14c-f	5.10g-j	6.22e	5.27fg	6.06d
30	4.95ij	5.73efg	5.58f	5.31fgh	5.31fg	5.91de
33	5.60fgh	6.46a-d	5.56f	6.60cd	5.62ef	6.49bc
36	6.52a-d	6.24b-e	6.38de	6.62cd	6.28cd	6.48bc
39	6.75ab	6.70abc	6.83abc	6.75bc	6.74ab	6.68ab
42	5.40ghi	5.66efg	6.70bcd	7.13a	6.71ab	7.03a
45	6.85a	7.02a	7.83abc	7.00ab	6.78ab	6.83ab
Overall Average[b]	4.83b	5.28a	5.51b	5.74a	5.53b	5.77a

[a] Each value is the mean $\log_{10}$ count/g of 3 chub packs.
Values for a given APC incubation temperature followed by no common letters are significantly ($P \leq 0.05$) different according to Duncan's multiple range test (2).

[b] Overall average values for a given APC incubation temperature followed by different letters are significantly ($P \leq 0.05$) different according to Duncan's multiple range test (2).

TABLE 2. Effect of storage at 0 C on MPNs of coliforms and *Escherichia coli* in ground beef prepared from "hot" and chilled beef carcasses.

	Coliforms		E. coli	
Days of Storage	Hot	Chilled	Hot	Chilled
0	12b[a]	14b	0c	7abc
3	7b	6b	0c	6abc
6	5b	17b	0c	3abc
9	2b	1b	0c	1c
12	9b	1b	9ab	1c
15	6b	0b	0c	0c
18	0b	12b	0c	2bc
21	3b	14b	0c	0c
24	4b	3b	0c	0c
27	22b	4b	0c	4abc
30	8b	10b	0c	10a
33	13b	151b	0c	0c
36	1b	19b	0c	1c
39	0b	5b	0c	5abc
42	0b	5b	0c	4abc
45	3b	4b	0c	1c
Overall Average[b]	6a	17a	1b	3a

[a]Each value is the mean MPN/g of 3 chub packs. Values for a given bacterial classification followed by no common letters are significantly ($P \leq 0.05$) different according to Duncan's multiple range test (2).

[b]Overall average values for a given bacterial classification followed by different letters are significantly ($P \leq 0.05$) different according to Duncan's multiple range test (2).

PHASE I - PART 3

Objective: To evaluate the effects of frozen lean source, patty size and patty treatment on palatability and cooking properties of ground beef patties.

THE EFFECTS OF FROZEN LEAN SOURCE, PATTY SIZE & PATTY TREATMENT ON PALATABILITY & COOKING PROPERTIES OF GROUND BEEF PATTIES

Introduction

The U.S. imports over 300 million pounds of frozen lean beef each year. Much of this imported beef is used in the production of ground beef. No research has been reported as to the effects on palatability and cooking properties of adding frozen lean from different sources. Also, patty sizes vary from less than 3.0 oz to more than 8 oz. It would be expected that patty size would have an effect on palatability and cooking traits. Little or no research has been reported in this area. The meat industry normally treats the fresh patty with a "knife-like" cut on each surface or a "waffle-like" impression on each surface. Research is needed to determine if these treatments have an effect on palatability and cooking traits.

This part of Phase I will address the questions of frozen lean source, patty size and patty surface treatment and their affects on ultimate palatability and cooking properties.

EXPERIMENTAL

FORMULATION

Fifteen ground beef formulations were prepared from varying raw material sources as outlined in Table 1. Formulations were prepared by adding 40% frozen lean (Mexican, Australian or domestic) to 60% choice lean trimmings

(unfrozen). Frozen lean was equivalent in grade to U.S. Cutter or Canner. Frozen lean was derived from the major and minor cuts of the entire carcass. Each formulation consisted of a minimum of 3000 lbs. Frozen meat blocks were passed through a Rietz grinder with a 3/8 in plate. Unfrozen, Choice trimmings were passed through a weiler grinder with a 3/8 in plate. Samples were randomly pulled after a 3 min mix and fat content was determined with an Anyl Ray Instrument. If necessary, the fat content was adjusted to 21 $\pm$ 2%. The average temperature of the Choice trimmings after the first grind was 24^{o} F. After mixing for 3 min with the frozen lean and grinding through the 1/8 in plate, the average temperature was 28^{o} F.

Two 250 pound batches were randomly selected from the 3000 pound batch after the final grind. Each 250 pound batch was randomly alloted to one of three patty sizes (8.0, 4.0 or 3.6 oz). Ground beef was passed through a FORMAX 24 patty machine. The average pressure during patty formulation was 75 to 80 lb/sq in.

Immediately after the patties were formed the surface was treated in one of three ways (Table 1). The surface was either 1) left plain; 2) cut with a knife-like" blade or 3) cut with a "waffle-like" blade. The knife cut was deeper (approximately 0.25 in) but the diameter of the hole was smaller than the waffle. The waffle cut was wider but not as deep as the knife cut (less than .15 in deep).

After patty formation, the patties were immediately passed via conveyor belt into a Northfield Spiroblast Ammonia freezer (-50^{o} F). The conveyor belt speed varied depending on the patty size. The internal temperature of the frozen patties averaged 20^{o} F after 12 to 16 min. After freezing, patties were placed in plastic bags and stored at -10^{o} F until shipment. Patties were

shipped to Beltsville, Md. via truck at 0^{o} F. Patties were stored at -20^{o} F until evaluated for sensory, physical and chemical properties.

COOKING METHOD & PROPERTIES

Frozen patties were broiled on electric Farberware grills. The time varied with the patty size. Preliminary trials indicated that in order to achieve the same degree of doneness, the 8.0 oz patty needed to cook 8 min on each side; the 4.0 oz patty 7 min; and the 3.6 oz patty 6 min. Degree of doneness was evaluated using an 8 point photographic scale with 8 = rate and 1 = well done. Degree of doneness was determined 5 min after sectioning. Total cooking loss was determined as the weight loss from the frozen to the cooked state. Measurements were obtained for raw and cooked patty height and diameter in order to evaluate changes during cooking.

PANEL SELECTION AND TRAINING

A 10-member panel was selected and trained in descriptive attributes by the procedures of Cross et al. (1978). The panel rated the following attributes on an 8-point structured scale: (a) tenderness and juiciness, with 8 = extremely tender and juicy; and 1 = extremely tough and dry; and (b) connective tissue amount with 8 = none and 1 = abundant. Panelists rated six samples at each of 18 sessions. Each treatment was replicated six times and samples to be evaluated in each session were selected via a table of random numbers.

INSTRON SHEAR

Ten patties from each treatment were broiled for determination of shear values. The cooked patties were cooled for at least 2 hr, and shear force was measured on each quarter of the patty with the single blade shearing device attached to the Instron as described by Cross et al. (1976b). Data were recorded for the maximum force required to shear through the meat patty.

STATISTICAL ANALYSIS

For each type of data, the analysis of variance was obtained using a sequential sums of squares approach. Since many of the contrasts were correlated, it was also necessary in the means analysis to use Scheffe's method to confirm in several instances that a difference between means was significant.

RESULTS & DISCUSSION

Table 2 presents data concerning the effect of frozen lean source on palatability traits. From the practical viewpoint, frozen lean source had no effect on palatability. There were a few significant effects but the magnitude of the difference is not important.

Frozen lean source from Mexico and Australia had significantly less total cooking loss than ground beef prepared from domestic frozen lean. Frozen lean from Australia had significantly less percent diameter change than patties prepared from domestic lean. Percent fat and water (as expected) was not significantly affected by frozen lean source.

Patty size had significant ($P < .05$) effects on tenderness, juiciness, amount of dectable connective tissue, and flavor intensity (Table 4). The 3.6 oz patties received significantly lower ratings in all of the aforementioned palatability traits when compared to the 4.0 and 8.0 oz patties. Patty size is likely more closely related to cooking and the ability of the patty to withstand high cooking temperatures.

As might be expected, as patty size decreased the percent cooking loss and percent diameter change increased (Table 5). Main effect interactions were highly significant ($P < .01$) for percent height change, thus further

means analysis is inappropriate. Degree of doneness ratings decreased (more well done) as patty size decreased--the only significant difference being between the 8.0 and 3.6 oz patties.

Patty treatments (knife, waffle or plain) did not enhance any palatability trait (Table 6). Untreated patties (plain) were more tender and juicy than patties receiving the knife or waffle treatment. The differences in connective tissue and flavor intensity were not significant but the trends were in favor of the untreated patty.

Patty treatments had non-significant effects on all cooking traits (Table 7). There appears to be no advantage (other than appearance) to subjecting the surface of the patty to a knife or waffle treatment. This data indicates that these treatments may actually have negative effects on palatability.

TABLE 1. Sample Formulations.

Formulation No.	Raw Meat Material	Patty Size, Oz	Patty Treatment
1	Mexican frozen lean + choice trimmings	8.0	Plain
2	Mexican frozen lean + choice trimmings	4.0	Plain
3	Mexican frozen lean + choice trimmings	3.6	Plain
4	Australian frozen lean + choice trim.	8.0	Plain
5	Australian frozen lean + choice trim.	4.0	Plain
6	Australian frozen lean + choice trim.	3.6	Plain
7	Domestic frozen lean + choice trimmings	8.0	Plain
8	Domestic frozen lean + choice trimmings	4.0	Plain
9	Domestic frozen lean + choice trimmings	3.6	Plain
10	Mexican frozen lean + choice trimmings	8.0	Knife
11	Mexican frozen lean + choice trimmings	8.0	Waffle
12	Mexican frozen lean + choice trimmings	4.0	Knife
13	Mexican frozen lean + choice trimmings	4.0	Waffle
14	Mexican frozen lean + choice trimmings	3.6	Knife
15	Mexican frozen lean + choice trimmings	3.6	Waffle

TABLE 2. Effect of frozen lean source on palatability traits.

Frozen Lean Source	Tenderness	Juiciness	Connective Tissue	Flavor Intensity	Instron Shear, kg
Mexican	6.07^{a}	5.8^{a}	5.4^{a}	5.5^{a}	8.37^{a}
Australian	6.0^{a}	5.5^{ab}	5.6^{a}	5.3^{a}	6.97^{b}
Domestic	5.8^{a}	5.3^{a}	5.3^{a}	5.2^{a}	7.22^{b}

n = 18 observations per mean

^{ab} means in the same row with different superscripts are different at the $P < .05$ level of probability.

TABLE 3. Effect of frozen lean source on cooking properties.

Frozen Lean Source	Total Cooking Loss, %	% Diameter Change	% Height Change	RAW % Fat, Wet	RAW % Water
Mexican	32.94^{a}	14.30^{ab}	18.44^{a}	21.52^{a}	61.35^{a}
Australian	33.85^{a}	13.86^{b}	15.36^{b}	22.65^{a}	58.42^{a}
Domestic	36.24^{b}	15.53^{a}	15.89^{b}	21.76^{a}	62.35^{a}

n = 48 observations per mean

[ab] means in the same row with different superscripts are different at the $P < .05$ level of probability.

TABLE 4. Effect of patty size on palatability traits.

Patty Size	Tenderness	Juiciness	Connective Tissue	Flavor Intensity	Instron Shear, kg
8 oz	6.1^{a}	5.7^{a}	5.6^{a}	5.6^{a}	7.91^{a}
4 oz	6.0^{a}	5.5^{a}	5.4^{a}	5.5^{a}	7.33^{a}
3.6 oz	5.6^{b}	5.3^{b}	5.2^{b}	5.1^{b}	7.22^{a}

n = 30 observations per mean

[ab] means in the same row with different superscripts are different at the $P < .05$ level of probability.

TABLE 5. Effect of patty size on cooking properties.

Patty Size	Total Cooking Loss, %	Degree of Doneness	% Diameter Change	% Height Change	% Fat, Wet	% Water
8 oz	32.58^{b}	3.0^{a}	12.19^{c}	18.46*	20.92^{b}	62.24^{b}
4 oz	33.75^{ab}	2.4^{ab}	14.02^{b}	14.05*	22.82^{a}	59.33^{a}
3.6 oz	34.02^{a}	2.0^{b}	16.02^{a}	16.78*	22.37^{a}	59.41^{a}

n = 48 observations per mean

* interactions highly significant, thus further means analysis is inappropriate.

ab means in the same row with different superscripts are different at the $P < .05$ level of probability.

TABLE 6. Effect of patty treatment on palatability traits.

Treatment	Tenderness	Juiciness	Connective Tissue	Flavor Intensity	Instron Shear,kg
Knife	5.7[a]	5.1[b]	5.2[a]	5.3[a]	8.27[a]
Waffle	5.7[a]	5.3[b]	5.2[a]	5.3[a]	8.04[a]
Plain	6.0[a]	5.8[a]	5.4[a]	5.5[a]	8.37[a]

n = 18 observations per mean

[ab] means in the same row with different superscripts are different at the $P < .05$ level of probability.

TABLE 7. Effect of patty treatment on cooking properties.

Patty Treatment	Total Cooking Loss, %	Degree of Doneness	% Diameter Change	% Height Change	% Fat, Wet	% Water
Knife	33.19[a]	2.6[a]	13.72[a]	20.80*	23.77[a]	58.85[a]
Waffle	31.59[a]	2.3[a]	13.16[a]	24.91*	21.34[b]	61.20[b]
Plain	32.94[a]	2.5[a]	14.30[a]	16.96*	21.52[b]	61.35[b]

n = 18 observations per mean

* interactions highly significant, thus further means analysis is inappropriate.

ab means in the same row with different superscripts are different at the $P < .05$ level of probability.

PHASE II - PART 1

Objective: Survey the current industry practices pertaining to ground beef production.

SURVEY OF CURRENT INDUSTRY PRACTICES PERTAINING TO GROUND BEEF PRODUCTION

Introduction

The tremendous expansion in consumer demand for ground beef has necessitated high-speed, large-volume product operations for ground beef. With this expansion has come variation in production systems. An interesting article appeared in the September 1976 issue of Meat Industry describing the many types of production layouts that are possible for ground beef depending on the volume of production.

During this past year, major commercial ground beef operations were interviewed and visited to determine the frequencies of certain processing systems, the type of equipment and raw material sources and the general comments concerning advantages and disadvantages of the systems.

SOURCE OF RAW MATERIAL

The majority of the commercial operations contacted utilize mature cow trimmings as the lean source with USDA Choice plates or 50% Choice trimmings as the fat source. While USDA Utility is the most frequent grade of cow used, several processors were using USDA Cutter and Canner grade beef. One-third of the 12 firms contacted used frozen rather than fresh cow meat; much of this being imported from Australia, New Zealand and South American countries. Some operations were using beef derived from the entire cow carcass, while others were using forequarter and hindquarter meat with the loins and ribs removed.

Still other companies used USDA Utility chucks, shanks and plates. Specifications often called for no visible tendons or ligament ends on shank meat. One processor using imported cow beef from a number of countries commented that he preferred Australian cow beef due to improved microbial levels and product texture. When frozen beef was used, it generally comprised 20-40% of the formulation.

PROCESSING SYSTEMS

Double grind systems seem to be the most prevalent in the industry. Considerable variation exists in the diameter of the initial grind with 0.63 cm, 0.95 cm, 1.27 cm, 1.59 cm, and 1.90 cm commonly used. Frozen beef is hydroflaked prior to mixing with initial ground product where frozen and fresh beef are used together. Lean and fat sources are ground separately for the initial grind prior to mixing before the final grind. In operations that utilize chopping as the initial system of size reduction, 4-8 bowl revolutions are made where the bowl capacity is 800-2000 pounds.

CO_2 snow or pellets are used in some operations for temperature reduction, however, preliminary data at our laboratory indicate that patties formulated from product whose CO_2 has been added tend to have excessive crumbliness. This observation was verified by one processor. The final grind size is most frequently 0.32 cm although 0.24 cm and 0.20 cm plates were also used. Some firms use bone collector plates on the final grind although one major fast-food chain will not permit their use due to the creation of mushiness in the product. Mechanical disinewing does not appear to be a common process as yet in practice by the ground beef industry. Flaking of beef for ground beef production seems to be declining due in part to claims that uneven degrees of cooked doneness and product puffing occurs in patties made from flaked meat.

FAT ANALYSIS

Major ground beef processors use rapid fat analyzers in continuous production systems with Anyl Ray being the most frequently used. Tolerance range for fat is often 2-3% depending on the buyer.

PATTY FORMATION

Capabilities exist in the industry for various size and shapes of patties. Ten (45 g), five (91 g), and four (113 g) patties per 454 g are frequent sizes observed under industry practice. Perforations (knife and waffle) are also commonly used. Formax appears to be the most popular equipment line for patty production. Product temperatures between -1° C and 2°C are typical for proper patty production. However, some operations have been able to process patties as high as 5° C.

FREEZING & PACKING 5-7 lbs polyethylene bags and frozen

Industry practice in this area consists of individual quick freezing of patties cryogenically in freezing tunnels. Patties are usually stacked 15-20 high in cartons containing about 300 patties per box, although many operations may use containers with only 50 per box. Some processors are vacuum packaging long individual stacks of patties prior to storage. Most boxes are lined with a moisture polyethylene bag. Some processors shrink-bagging entire palletized volumes of boxes containing patties.

PHASE II - PART 2

Objective: To determine the effects of grinding, flaking and combinations of these two processes in the production of precooked and non-precooked beef patties made from Choice trimmings and Cutter and Canner cow trimmings.

EFFECTS OF GRINDING VS FLAKING IN THE PRODUCTION OF BEEF PATTIES

Introduction

Flaked, formed and cleaved steak-like products have been successfully produced in the meat industry. Flaking has also been used in some operations for the production of beef patties. However, some fast food establishments are no longer using flaked patties due to claims of uneven doneness in cooked product arising from patties swelling in the center during cooking. There have also been some claims that flaked patties do not hold together well especially in cookery.

The intent of this study was to evaluate to evaluate flaking vs grinding using beef materials differing widely in maturity (Choice vs Cutter-Canner cow) in the production of both raw-quick frozen and precooked-quick frozen patties.

EXPERIMENTAL

Raw materials for use in this project consisted of USDA Cutter and Canner cow forequarter and hindquarter beef, USDA lean trimmings from top sirloin butts and regular USDA Choice table (fat) trimmings. The Cutter and Canner cow meat average 8.7% fat, the Choice lean trimmings 7.9% fat and the Choice fat trimmings 38.5%. Formulations were processed to possess 24$\pm$ 1% fat utilizing the Foss-let fat analyzer as the method of fat analysis.

Treatments that were ground were processed through a 1.99 cm plate initially followed by grinding through a 0.32 cm plate. The Cutter and Canner cow meat was frozen and thus was subjected to pre-breaking into pieces approximately 7.6 cm in all dimensions. Treatments were mixed for 2 min prior to final particle reduction steps.

Flaking was performed on the Urschel Commitrol 120 head where flaking was the final operation. Treatments that were flaked first and then ground were flaked using the Urschel Commitrol 750 head followed by final grinding with the 0.32 cm plate. Following grinding or flaking, 113 g patties were processed. In the case of patties to be frozen from the raw state, they were subjected to freezing at -38 C on a moving belt spiral freezer. Patties that were precooked prior to the same freezing process were cooked in a Heat and Control unit for a total time on a moving belt of 140 sec. The wet bulb temperature in cooking was 88 C, while the dry bulb temperature was 199 C. Product was stored at -26 C prior to the appropriate analyses.

Two batches were formulated per treatment. The Choice fat trimmings were used with the two lean sources to produce the 24% fat levels required. All combinations of source of lean trimmings, processing methods, state of product prior to cookery and batches depicted in Table 1 were processed.

Sensory panel training and procedures, physical measurements and chemical analyses for this phase and part were identical to those described in Phase I-Part 1.

RESULTS AND DISCUSSION

Tenderness scores did not differ substantially among the various treatment combinations (Table 2). In some comparisons by similar processing and state of product combinations, patties made from Choice trimmings had higher scores for tenderness than was the case for Cutter-Canner cow trimmings.

Connective tissue amount scores were also influenced more by source of lean trimmings rather than method of processing and state of product when cooked for evaluation. Flaking did not alter the connective tissue component, such that it was less detectable by the sensory panel.

Juiciness scores and rating for ground beef flavor intensity also were not greatly affected by the variable studied. Precooked patties, while essentially cooked twice received similar scores for juiciness as their counterpart cooked from the raw state for sensory analyses.

Instron values and cooking characteristics are presented in Table 4. Instron maximum shear force values and total work did reflect a higher degree of tenderness in formulations made from Choice trimmings in contrast to Cutter-Canner cow trimmings. With the exception of ground Cutter-Canner cow formulations, precooked patties had lower maximum shear and total work values than patties cooked from the frozen raw form just prior to evaluation.

Several interesting trends were apparent for cooking characteristics. Patties cooked from the frozen-raw state underwent greater change (reduction) in patty diameter during cooking than precooked and then recooked patties. However, the opposite situation was true for patty height. Thus, in essence, patties that were cooked from the frozen-raw state tended to shrink more from the outside periphery than the top and bottom in comparison to precooked patties. The differences between patty diameter changes and patty height changes in frozen raw vs precooked patties were less in ground formulations regardless of the source of lean trimmings.

As might be expected, the cooking losses were much greater for patties cooked from the frozen-raw state than was the case for precooked patties. This can be misleading since the weight loss during precooking has not been accounted for.

With the exception of Choice-ground-precooked patties having higher cooking losses than similar Choice precooked patties made from flaked materials, source of lean trimmings and method of processing did not affect cooking losses.

Chemical composition for fat and moisture values are depicted in Table 5. Values classified under "raw patties" would have received no cooking for raw product and one cooking for precooked product. Values under "cooked patties" would have been cooked once for raw product and twice for precooked samples. Cutter and Canner cow beef patties had higher moisture values in raw patties than was the case for patties in the raw form from all Choice materials. Precooked patties under the raw category were similar in percent moisture regardless of the source of lean trimming. This might imply that precooking removed more moisture in product made from cow trimmings than from Choice beef. This conclusion is verified by the values for percent fat on a wet basis for Cutter and Canner cow patties, where little differences exist between raw and precooked patties; while on a dry matter basis the percent fat is much lower in precooked than raw patties for these formulations. For patties made from Choice materials, flaking produced similar levels of moisture whether precooked or not, but resulted in much higher percentages of fat in the product on both a wet and dry matter basis. This would imply that for flaked Choice patties, precooking is removing more fat than is the case for patties manufactured from cow materials.

It is interesting to note that in comparisons under the category of raw patties vs cooked patties, raw patties decreased in percent moisture for the broiling type of cookery, while the precooked patties being cooked for the second time responded in the opposite manner for moisture values. Fat

levels generally went down substantially for the broiling cookery regardless of the state of the product. These results would indicate that in the second cooking (broiling) for precooked patties they are losing more fat in the cooking process than raw patties cooked by broiling for the first time. Values shown for TBA did not indicate a high degree of rancidity for any type of formulation.

CONCLUSIONS

Neither method of processing (grind vs flake) nor state of product when cooked for evaluation (precooked vs frozen-raw) exerted much of an effect on palatability, Instron values, or cooking characteristics in this study. Patties made from Cutter and Canner cow trimmings did have slightly lower tenderness as measured by sensory panel and Instron values.

Broiling the product from the frozen-raw state or the frozen precooked state produced the major differences in this phase of the project. Patties cooked from the frozen-raw state: 1) required less Instron force and work to shear samples; 2) shrunk more in diameter, but less in height; 3) possessed higher cooking losses; and 4) lost more moisture and less fat during cooking than comparable formulations cooked from the precooked state.

TABLE 1. Experimental Design.

Source of Lean Trimmings	Processing Method	State of Product Prior to Cookery for Evaluation	Batch
Choice trimmings from top sirloin butts	Initial grind 1.99 cm plate followed by final grind of 0.32 cm.	Raw Precooked	1,2
Cutter and Canner cow trimmings			
	Flaking with the Urschel Commitrol 120 head.		
	Flaking with the Urschel Commitrol 750 head followed by final grind of 0.32 cm.		

TABLE 2. Scores for tenderness and connective tissue amount in ground and flaked patties.

Source of Lean Trimmings	Method of Processing	State of Product	Batch	Palatability Trait: Tenderness Score	Palatability Trait: Connective Tissue Amt. Score
Choice	Grind	Raw	1	5.9	4.5
Choice	Grind	Raw	2	5.9	5.0
Choice	Grind	Precooked	1	6.0	4.8
Choice	Grind	Precooked	2	6.0	4.8
Choice	Flaked	Raw	1	5.3	5.0
Choice	Flaked	Raw	2	5.7	4.1
Choice	Flaked	Precooked	1	5.6	5.0
Choice	Flaked	Precooked	2	6.0	5.0
Choice	Flaked & Ground	Raw	1	5.8	5.0
Choice	Flaked & Ground	Raw	2	6.3	5.4
Choice	Flaked & Ground	Precooked	1	6.4	5.2
Choice	Flaked & Ground	Precooked	2	6.0	5.2
Cutter & Canner	Grind	Raw	1	5.5	4.3
Cutter & Canner	Grind	Raw	2	5.4	4.2
Cutter & Canner	Grind	Precooked	1	6.0	4.5
Cutter & Canner	Grind	Precooked	2	5.8	3.2
Cutter & Canner	Flaked	Raw	1	5.1	4.1
Cutter & Canner	Flaked	Raw	2	5.4	4.3
Cutter & Canner	Flaked	Precooked	1	5.8	4.4

Cont'd

TABLE 2. Scores for tenderness and connective tissue amount in ground and flaked patties. (Continued)

Source of Lean Trimmings	Method of Processing	State of Product	Batch	Palatability Trait: Tenderness Score	Palatability Trait: Connective Tissue Amt. Score
Cutter & Canner	Flaked	Precooked	2	5.2	4.2
Cutter & Canner	Flaked & Ground	Raw	1	5.4	3.9
Cutter & Canner	Flaked & Ground	Raw	2	5.4	4.1
Cutter & Canner	Flaked & Ground	Precooked	1	5.6	4.2
Cutter & Canner	Flaked & Ground	Precooked	2	5.2	4.0

TABLE 3. Scores for juiciness and flavor intensity in ground and flaked patties.

Source of Lean Trimmings	Method of Processing	State of Product	Batch	PALATABILITY TRAIT Juiciness Score	Flavor Intensity Score
Choice	Grind	Raw	1	5.2	4.4
Choice	Grind	Raw	2	5.1	4.3
Choice	Grind	Precooked	1	5.2	4.3
Choice	Grind	Precooked	2	5.1	4.1
Choice	Flaked	Raw	1	5.0	4.3
Choice	Flaked	Raw	2	4.7	4.2
Choice	Flaked	Precooked	1	5.1	4.2
Choice	Flaked	Precooked	2	5.2	4.4
Choice	Flaked & Ground	Raw	1	4.9	4.4
Choice	Flaked & Ground	Raw	2	5.5	4.7
Choice	Flaked & Ground	Precooked	1	5.1	4.3
Choice	Flaked & Ground	Precooked	2	4.8	4.4
Cutter & Canner Cow	Grind	Raw	1	5.0	4.6
Cutter & Canner Cow	Grind	Raw	2	4.9	4.6
Cutter & Canner Cow	Grind	Precooked	1	5.2	4.3
Cutter & Canner Cow	Grind	Precooked	2	5.6	4.4
Cutter & Canner Cow	Flaked	Raw	1	4.8	4.2
Cutter & Canner Cow	Flaked	Raw	2	5.2	4.5
Cutter & Canner Cow	Flaked	Precooked	1	5.2	4.3
Cutter & Canner Cow	Flaked	Precooked	2	4.9	4.5
Cutter & Canner Cow	Flaked & Ground	Raw	1	4.8	4.2
Cutter & Canner Cow	Flaked & Ground	Raw	2	4.9	4.4
Cutter & Canner Cow	Flaked & Ground	Precooked	1	5.0	4.3
Cutter & Canner Cow	Flaked & Ground	Precooked	2	4.5	4.4

TABLE 4. Instron values and cooking characteristics for ground and flaked patties.

			INSTRON COOKING CHARACTERISTICS				
Source of Lean Trimmings	Method of Processing	State of Product	Kg Instron Max. Shear Force	Instron Total Work	% Change During Cooking in Pattie Diameter	% Change During Cooking in Patty Height	% Cooking Loss
Choice	Grind	Raw	13.7	42.5	18.6	21.6	42.5
Choice	Grind	Precooked	11.6	39.6	13.4	28.2	28.0
Choice	Flaked	Raw	13.2	47.4	22.1	18.1	38.4
Choice	Flaked	Precooked	12.9	41.0	9.7	26.7	19.1
Choice	Flaked & Ground	Raw	12.4	45.0	21.2	17.8	41.5
Choice	Flaked & Ground	Precooked	11.4	33.0	5.0	26.1	15.9
Cutter & Canner Cow	Grind	Raw	15.9	48.8	19.3	17.1	40.9
Cutter & Canner Cow	Grind	Precooked	17.9	50.9	10.0	26.5	26.7
Cutter & Canner Cow	Flaked	Raw	19.0	60.7	20.2	18.0	40.0
Cutter & Canner Cow	Flaked	Precooked	17.5	50.1	7.9	28.8	26.2
Cutter & Canner Cow	Flaked & Ground	Raw	18.2	61.9	20.0	13.9	39.8
Cutter & Canner Cow	Flaked & Ground	Precooked	15.2	45.4	5.9	31.0	24.5

TABLE 5. Fat and moisture values for ground and flaked patties in the raw and cooked form.

			RAW PATTIES			COOKED PATTIES			
Source of Lean Trimmings	Method of Processing	State of Product	% Moisture	% Fat-Wet Matter Basis	% Fat-Dry Matter Basis	% Moisture	% Fat-Wet Matter Basis	% Fat-Dry Matter Basis	TBA Values
Choice	Grind	Raw	58.7	26.4	63.6	51.8	20.6	42.7	1.13
Choice	Grind	Precooked	51.7	28.7	59.4	53.6	26.3	56.5	0.54
Choice	Flaked	Raw	55.8	28.9	65.4	53.1	22.8	48.3	0.85
Choice	Flaked	Precooked	54.1	22.8	59.5	56.2	19.8	45.2	0.48
Choice	Flaked & Ground	Raw	53.5	31.2	67.1	51.6	22.2	45.8	1.19
Choice	Flaked & Ground	Precooked	53.2	24.5	52.3	57.2	24.9	58.3	0.51
Cutter & Canner Cow	Grind	Raw	61.3	25.2	65.3	52.3	22.9	48.0	0.54
Cutter & Canner Cow	Grind	Precooked	53.5	25.4	56.0	54.1	21.2	46.2	0.38
Cutter & Canner Cow	Flaked	Raw	61.2	23.0	59.2	53.1	20.8	44.4	0.95
Cutter & Canner Cow	Flaked	Precooked	54.8	25.4	56.0	54.7	20.0	43.9	1.11
Cutter & Canner Cow	Flaked & Ground	Raw	60.C	25.8	64.6	54.2	20.4	44.6	0.60
Cutter & Canner Cow	Flaked & Ground	Precooked	51.2	28.8	58.2	54.0	22.8	49.6	0.29

Phase II - Part 3

Objective: To ascertain the effects of grinding, chopping and combinations of these two processes in the production of beef patties made from Choice chucks and Cutter and Canner cow trimmings.

EFFECTS OF GRINDING VS CHOPPING IN THE PRODUCTION OF BEEF PATTIES

Introduction

Several systems exist in the industry for initial partical reduction prior to the final grinding operation in the production of ground beef. Chopping of raw materials through the use of a food chopper or silent cutter has been used to produce "chopped beef" that has been packaged in keeper casings for distribution to other processors, retailers, etc., for final grinding. Industry comments relative to chopping have been favorable in terms of brighter color, less purge loss and longer shelf-life. However, research has not been conducted relative to assessing the importance of chopping in terms of palatability values. Thus, it was decided to evaluate chopping in comparison to grinding as the initial stage of particle reduction using Choice and Cutter-Canner cow materials.

EXPERIMENTAL

Raw materials for use in this phase consisted of USDA Cutter and Canner cow, forequarter and hindquarter beef, USDA chuck and neck trimmings and USDA regular chuck trimmings (52% fat). The Cutter and Canner cow meat averaged 10% fat, while the chuck and neck trimmings were 18% fat. Formulations were processed to possess 24 ± 1% fat utilizing the Anyl Ray fat analyzers as the method of fat analysis treatments that were ground were processed through a 1.58 cm plate initially followed by grinding through a 0.32 cm plate. All

treatments were mixed for 45 sec between the initial grinding or chopping and the final grind operation.

Chopping was performed in a 363.3 kg capacity chopper using 3 knives. Total chopping time was 30 sec or a total of 10 bowl revolutions. In treatments designated for chopping, after the chopping step, the materials were mixed for 45 sec prior to the final grinding procedure with the 0.32 cm plate. Patties (86 g) were processed and the product was stored at -26 c prior to the appropriate analyses.

Two batches were formulated per treatment. All combinations of the formulations, processing procedures and batches depicted in Table 1 were processed.

Sensory panel training and procedures, physical measurements and chemical analyses for this phase and part were identical to those described in Phase I - Part 1.

RESULTS AND DISCUSSION

In terms of definition for initial and final tenderness and connective tissue amount as assessed by the sensory panel, initial tenderness = rating after 5 chews, final tenderness = rating after 15 chews, initial connective tissue amount = rating after 15 chews, final connective tissue amount = rating after complete mastication of the sample by the panelist. Formulations made from all Choice materials received higher initial and final tenderness ratings than did patties made from Cutter and Canner trimmings with Choice trimmings added for fat adjustment. There was a trend especially for Choice formulations of higher tenderness scores for product initially chopped rather than ground or ground and chopped combined. Scores assigned for initial tenderness did not

appreciably differ from those for final tenderness.

Connective tissue amount scores, both initial and final also reflected higher values (less organoleptically determined connective tissue) for both Choice vs Cutter-Canner formulations and chopped vs grind and 50% grind - 50% chopped treatments. It would appear that chopping the material prior to final grinding does create changes in the connective tissue where they are slightly less detectable in the final patty product. There were some batch differences for Choice 50% ground -50% chopped and Cutter-Canner chopped than ground formulations.

Juiciness scores were not greatly affected by the treatment variable of this study, although Cutter-Canner ground and 50% ground - 50% chopped formulations received the lowest ratings for juiciness. Cutter and Canner formulations yield patties rated lower in flavor intensity than companion patties made from all Choice trimmings.

Instron maximum shear force measurements essentially revealed no differences among sources of raw material or processing methods. However, total Instron work values indicated greater work (lower tenderness in treatments manufactured from Cutter and Canner cow trimmings. Visual scores for degree of doneness were influenced more by batch than any of the other variables studied. It is interesting to note that patties processed by chopping and then grinding Cutter and Canner cow beef had the least change in patty height upon cooking and were also low in cooking loss. Muscle from older maturity cattle is reputed to have better water holding capacity and chopping has been acclaimed to produce less purge loss than grinding.

Differences in the percent moisture in cooked patties appeared to be influenced as much by batch as source of lean and processing method. There was

a slight trend on a dry matter basis for treatments initially all chopped prior to grinding to have more fat in the cooked product than was the case for other treatments.

CONCLUSIONS

Generally, grinding, chopping or a combination of grinding and chopping as the initial particle reduction system did not greatly affect palatability, physical or chemical values. There was some tendency for chopping to yield slightly higher tenderness scores and less organoleptically assessed connective tissue than grinding. Patties made from all Choice materials had higher tenderness scores, less detectable connective tissue ratings and lower total Instron work than similar patties made from Cutter-Canner cow trimmings with Choice fat trimmings. In summary, it would appear that chopping as an initial system of reducing trimming size is as good or slightly better from a palatability standpoint as the double grind system.

TABLE 1. Experimental design.

Source of trimmings, formulations	Processing procedures	Batches
USDA choice chuck lean trimmings with USDA choice chuck fat trimmings	Initial grind--1.58 cm followed by final grind of 0.32 cm.	1,2
USDA cutter and canner cow trimmings with USDA choice chuck fat trimmings	Chopping (30 sec.--10 revolutions) then final grind--0.32 cm.	
	Divide the lean and fat trimming in half. Chop 50% of the trimmings (30 sec.--10 revolutions). Grind 50% of the trimmings--1.58 cm. mix together and final grind 0.32 cm.	

TABLE 2. Tenderness and connective tissue ratings for chopped and ground beef.

		Palatability attribute			
Formulation, processing	Batch	Initial tenderness	Final tenderness	Initial connective tissue amount	Final connective tissue amount
Choice--all grind	1	5.3	5.4	4.6	4.5
Choice--all grind	2	5.2	5.3	4.8	4.9
Choice--50% initial grind and 50% initial chop, then final grind	1	4.9	5.1	4.5	4.5
Choice--50% initial grind and 50% initial chop, then final grind	2	5.4	5.7	4.9	4.8
Choice--chop, then final grind	1	5.6	5.8	5.1	5.2
Choice--chop, then final grind	2	5.5	5.8	5.2	5.5
Cutter and canner--all grind	1	4.5	4.6	4.0	3.9
Cutter and canner--all grind	2	4.5	4.7	4.1	4.1
Cutter and canner--50% initial grind and 50% initial chop, then final grind	1	4.8	4.8	4.1	4.0
Cutter and canner--50% initial grind and 50% initial chop, then final grind	2	4.5	4.6	4.1	4.1
Cutter and canner--chop, then final grind	1	5.0	5.2	4.5	4.4
Cutter and canner--chop, then final grind	2	4.6	4.7	4.3	4.3

TABLE 3. Juiciness and Flavor intensity ratings for chopped and ground beef.

Formulation, processing	Batch	Palatability attribute: Juiciness	Palatability attribute: Ground beef, flavor intensity
Choice--all grind	1	4.8	4.3
Choice--all grind	2	4.9	4.5
Choice--50% initial grind and 50% initial chop, then final grind	1	4.6	4.5
Choice--50% initial grind and 50% initial chop, then final grind	2	5.3	4.5
Choice--chop, then final grind	1	5.1	4.2
Choice--chop, then final grind	2	5.1	4.5
Cutter and canner--all grind	1	4.2	4.0
Cutter and canner--all grind	2	4.5	3.8
Cutter and canner--50% initial grind at 50% initial chop, then final grind	1	4.5	4.0
Cutter and canner--50% initial grind at 50% initial chop, then final grind	2	4.2	3.8
Cutter and canner--chop, then final grind	1	4.8	4.1
Cutter and canner--chop, then final grind	2	4.6	4.2

TABLE 4. Instron and cooking characteristics for chopped and ground beef.

		Characteristic					
Formulation, processing	Batch	Maximum instron shear Kg	Instron total work	Degree of doneness	Change in patty diameter, %	Change in patty height, %	Cooking loss, %
Choice--all grind	1	17.0	54.5	2.8	19.8	18.7	37.6
Choice--all grind	2	14.3	52.9	2.0	21.2	5.9	39.5
Choice--50% initial grind and 50% initial chop, then final grind	1	15.8	52.3	2.4	24.3	17.9	40.4
Choice--50% initial grind and 50% initial chop, then final grind	2	16.9	56.5	2.1	21.2	6.4	41.6
Choice--chop, then final grind	1	15.4	51.7	2.5	22.6	18.1	44.2
Choice--chop, then final grind	2	14.5	49.6	2.0	22.0	10.2	46.0
Cutter and canner--all grind	1	18.2	61.9	2.2	21.3	13.5	38.3
Cutter and canner--all grind	2	14.8	57.6	2.0	17.5	11.0	39.6
Cutter and canner--50% initial grind and 50% initial chop, then final grind	1	17.4	60.6	2.2	22.4	13.6	42.6
Cutter and canner--50% initial grind and 50% initial chop, then final grind	2	16.4	60.1	2.0	21.9	13.3	44.7
Cutter and canner--chop, then final grind	1	16.4	57.0	2.9	20.0	9.0	37.4
Cutter and canner--chop, then final grind	2	16.8	58.4	2.0	22.7	4.0	39.9

TABLE 5. Chemical values for cooked chopped and ground beef.

Formulation, processing	Batch	Values: Moisture, %	Fat-wet basis, %	Fat, dry basis, %
Choice--all grind	1	55.4	16.5	37.0
Choice--all grind	2	52.9	22.0	46.6
Choice--50% initial grind and 50% initial chop, then final grind	1	56.1	15.7	35.8
Choice--50% initial grind and 50% initial chop, then final grind	2	53.4	20.2	46.6
Choice--chop, then final grind	1	50.0	23.6	47.3
Choice--chop, then final grind	2	54.3	20.4	44.6
Cutter and canner--all grind	1	51.4	20.3	41.8
Cutter and canner--all grind	2	53.1	19.7	42.0
Cutter and canner-50% initial grind and 50% initial chop, then final grind	1	54.6	16.5	35.4
Cutter and canner--50% initial grind and 50% initial chop, then final grind	2	51.4	22.3	44.9
Cutter and canner--chop, then final grind	1	53.3	21.0	44.9
Cutter and canner--chop, then final grind	2	51.4	22.1	45.3

PHASE VI - PART 1-FAT SOURCES

Objective: To determine the effects of 5 sources of fat: 1) Choice plates; 2) Choice trimmings; 3) Choice flanks; 4) 50-50 Choice trimmings with kidney fat; and 5) 50-50 kidney fat with brisket fat on ground beef quality.

PART 2-FAT LEVELS

Objective: To determine the effects of various levels of fat (12, 18, 24, and 30%) on ground beef quality.

EFFECTS OF VARIATIONS IN FAT LEVEL AND SOURCE ON GROUND BEEF QUALITY

Introduction

Several studies in the past have attempted to determine the major quality characteristics consumers look for when purchasing ground beef. Glover (1964) determined that the primary attribute consumers associate with ground beef quality is the degree of leanness. Mize (1972) and Law et al. (1965) revealed that consumers identify color first, and leanness second in the area of quality. USDA regulations stipulate that 30% fat is the maximum allowable fat level in ground beef.

Research by numerous workers has shown that consumers can distinguish ground beef manufactured with different fat levels. Cole, Ramsey, and Odom (1960) determined that consumers preferred ground beef containing greater than 15% fat, while a trained sensory panel preferred patties in direct proportion to fat content with product manufactured at 35% fat receiving the highest scores for palatability. Their study concluded that leaner ground beef is generally less palatable than ground beef containing at least 25% fat. Mize (1972) and Law (1965) found that consumers preferred ground beef in the following order according to fat level; 15%, 25% and 35%. Additional research by Glover (1964) demonstrated that consumers preferred ground beef containing 20% when compared with ground beef formulated to 16, 25, and 30% fat levels. There has been little if any research conducted to determine the effect of fat source or type on ground beef quality. The objective of this study was to determine the effects of type and level of fat on ground beef quality.

EXPERIMENTAL FOR PART I AND II

GRINDING

USDA Utility chucks, Choice plates, Choice trimmings, Choice flanks, kidney and brisket fat were purchased and trucked to the abattoir at the Beltsville Agricultural Research Center. All raw materials were ground through a 1.9 cm plate, during which a 5.9 kg grab sample was collected for fat analysis. The fat content was estimated by the Anal-Ray fat analyzer. Treatments (22.7 kg in size) were then formulated to contain 12, 18, 24, or 30% fat by mixing the Utility chucks with one of the fat types for a total of 3 min. The meat was then ground through a 0.32 cm plate, after which 145 gm patties were formed on the Hollymatic No. 200 patty machine, boxed, and frozen at -24^{o} C. After 24 hours 3 patties per package were wrapped in butcher paper, boxed and stored at -13^{o} C.

The procedures for cooking, chemical analysis, physical changes, and sensory panel evaluation were generally the same as those described under Phase I, Part I. The percent diameter change, percent height change, and final cooked temperature were not measured. Cooking times to achieve the same degree of doneness varied with the percent fat. Patties containing 24% fat were broiled 8 min on one side turned and broiled 6 min on the other size; 30% fat broiled 7 min on one side turned and broiled 5 min on the other side; 12% fat broiled 5 min on one side turned and broiled 5 min on the other side, turned and broiled 5 more min on the first side; and 18% fat broiled 4 min on one side turned, broiled 4 min on the other side; turned and broiled 6 min more on the first side. The sensory evaluation panel only evaluated final tenderness, final connective tissue amount, juciness, and ground beef flavor intensity (refer to Phase I, Part 1). In addition panelists evaluated the degree of coating of their mouths.

RESULTS AND DISCUSSION PART I

Table 2 shows the results of palatability and Instron measurements on ground beef. Tenderness was not affected by the fat source used, however, the 30 percent fat level yielded higher ($P < .05$) tenderness ratings for 50-50 Choice trimmings/Kidney fat and 50-50 brisket fat/kidney fat then product made to have 24 percent fat. Instron total work values also reflected greater tenderness in product possessing 30% fat vs. treatments with 24% fat. Juiciness also was only significant ($P < .05$) for fat level, with patties made to have 30% fat yielding higher juciness scores than 24% fat product. Ground beef flavor intensity scores, connective tissue amount scores, degree of doneness scores and cooking loss percentages were not significantly ($P > .05$) different for fat source or fat level (data not shown). Since sensory panel scores for connective tissue amount revealed no difference due to the type of fat, no chemical determination of connective tissue was done. Table 3 shows that the type of fat, rather than the level of fat, influenced sensory scores for mouth coating due to fat. Product made from choice plates were scored significantly lower ($P < .05$) then product using Choice flanks as the fat source with Choice flanks rated higher ($P < .05$) 50% brisket fat-50% kidney fat product. It should be noted that the magnitude of the difference between fat sources, 6.19 to 6.41, is of no practical value.

The percent fat was determined by ether extract to confirm that treatments were formulated to 24% or 30% fat (Table 4). When ground beef patties were cooked the percent fat was reduced for all treatments, with the 30% fat treatments generally retaining more fat than 24% fat treatments post cooking. The percent moisture was also determined (Table 5). Increased fat content resulted in lower percent moisture raw, as would be expected. The percent moisture decreased when ground beef patties were cooked.

CONCLUSIONS

The results of the data indicates that the type of fat used in the manufacture of ground beef does not affect the quality of ground beef. Scores for mouth coating due to fat were the only parameter in which a significant difference due to the type of fat was found, however, the magnitude of the difference was of minor importance. Level of fat in the formulation (24% vs. 30%) did have a significant effect on tenderness, juiciness, shear force, and total shear work, with 30% fat having higher palatability scores and reduced Instron values. The effect of fat level will be discussed in more detail in part II.

RESULTS AND DISCUSSION PART II

Four treatments of ground beef were formulated to contain 12, 18, 24 and 30% fat as discussed under the Experimental portion pertaining to grinding in parts I and II. Chemical determination of the percent fat, by ether extract revealed that the treatments were in fact formulated to 16, 20, 24 and 30% fat (Table 6). Throughout the rest of the paper these treatments will be referred to as 16, 20, 24 and 30% fat. The % moisture of raw ground beef patties was highest for the 16 % fat treatment. Upon cooking, all treatments lost moisture, with the 16% fat treatment retaining the most moisture after cooking (Table 7). The results of sensory panel evaluation and Instron mechanical shear are shown in Table 8. Tenderness was affected by the % fat in ground beef, with the 16% fat treatment being significantly ($P<0.05$) less tender then either 24% or 30%. Sensory panel scores for juiciness were significantly ($P< 0.05$) lower for patties containg 16% fat compared to all other treatment scores. In addition patties containing 30% fat received significantly ($P< 0.05$) higher scores for juiciness than all other treatments. Since

patties processed to contain 16% fat had less moisture, these results would support the positive effect fat has on juiciness. There was significantly more ($P < 0.05$) detectable connective tissue in patties formulated to 16% fat than 24 % or 30%. The magnitude of the difference between all four treatments for detectable connective tissue amount is of minor importance. However, patties containing 24% fat received the highest scores for connective tissue amount and it had the lowest total amount of chemically determined total collagen (Table 9). Scores for mouth coating due to fat were significantly ($P < 0.05$) higher for 30% fat samples compared to all other treatments. This could be attributed to the fact that patties containing 30% fat had the most fat of all four treatments evaluated. Treatments formulated to 24 and 30% fat required significantly less ($P < 0.05$) total Instron work to shear than was the case for patties made to have 16 or 20% fat. Mention should be made of the relationship between Instron total work and sensory panel scores for tenderness. As the % fat increased, total work decreased and sensory panel scores increased, reflecting a more tender product. The ground beef flavor intensity, degree of doneness, Instron shear force (Kg) and % cooking losses were all nonsignificantly ($P > 0.05$). (data not shown) It was surprising to note that ground beef containing different percentages of fat did not differ in % cooking loss. Partial explanation for this phenomenon can be seen in Table 10. The lower the % fat in ground beef, the less fat was lost and the more moisture was lost during cooking. On the other hand, increasing levels of fat in ground beef resulted in more fat lost and more moisture retained when cooked. Generally, the patties are cooked, the fat which is lost accumulates in the pan during frying and may be visible to the housewife, whereas the moisture lost is not visible. Glover (1964) determined that consumers dislike ground beef containing high levels of fat because of excessive

shrinkage when cooked. The data presented here reveals that in fact there is no difference in the total cooking loss of patties containing 16, 20, 24 or 30% fat. However, it is likely that the visible cooking loss, (fat drippings) is different and greatest in patties possessing 30% fat.

CONCLUSIONS

As the % fat increased in ground beef from 16 to 30% fat tenderness and juiciness scores assigned to cooked patties increased, while Instron total work decreased. Since total losses in cooking did not differ among the various fat levels of this study, product manufactured to contain 30% fat may have a higher ratio of edible portion to cost because 30% fat ground beef usually is priced lower than product at 24% and lower fat levels.

TABLE 1 - Part 1. Experimental design showing the sources of fat using in processing ground beef.

FAT SOURCE	FAT LEVEL 24%	30%
Choice Plates	X	X
Choice Trimmings	X	X
Choice Flanks	X	X
Choice Trimmings/Kidney Fat	X	X
Brisket Fat/Kidney Fat	X	X

Table 1 - Part II. Experimental design employing different fat levels.

Fat Source	FAT LEVEL 12%	18%	24%	30%
Choice Plates	X	X	X	X

TABLE 2. Palatability ratings for patties incorporating fat from various sources

Parameter	Fat Source	Fat Level 24%	Fat Level 30%
Tenderness	TRIM/KID[b]	5.35[d]	5.84[e]
	BRISKET/KID	5.38[d]	5.75[e]
Juciness	AVERAGE[c]	5.26[d]	5.54[e]
Shear Force (Kg)	AVERAGE	8.66[d]	7.86[e]
Total Work	AVERAGE	54.51[d]	48.92[e]

b = choice trimmings and kidney fat.

c = average; the average of all fat sources was significant for fat level.

d,e = paired means in the same row with different letters are significantly different (P 0.05).

TABLE 3. Mouth coating scores assigned patties incorporating fat from various sources

Fat Source	Average Score of Fat Level
Choice Plates	6.20[b,d]
Choice Trimmings	6.27
Choice Flanks	6.41[c]
Trim/Kid[a]	6.30
Brisket/Kid	6.19[d]

a = 50-50 Choice trimmings/kidney fat, 50-50 brisket fat/kidney fat.

b,c,d = means with different superscripts are significantly different (P .05).

TABLE 4. Means for percent fat in raw and cooked patties incorporating fat from various sources

	Percent Chemically Determined Fat[b]			
	24%		30%	
Type of Fat	Raw	Cooked	Raw	Cooked
Choice Plates	24.8	20.9[c]	29.5	24.6[c]
Choice Trimmings	25.0	22.2[c]	30.9	24.2[c]
Choice Flanks	24.4	22.2[c]	29.9	23.4[c]
50-50 Trim/Kid[a]	26.2	19.9[c]	28.1	21.9[c]
50-50 Brisket/Kid	27.3	22.8[c]	28.2	22.7[c]

a = 50-50 Choice trimmings/Kidney fat.

b = Analysis of Variance was conducted only on percent fat in cooked patties.

c = Means in the same row or column for percent fat cooked with different superscripts are significantly different (P 0.05).

TABLE 5. Means for percent moisture in raw and cooked patties incorporating fat from various sources.

	FAT LEVEL Percent Moisture[a]			
	24%		30%	
	Raw	Cooked	Raw	Cooked
Choice Plates	58.6	52.0[b]	55.8	51.4[b]
Choice Trimmings	60.2	50.6[b]	54.7	51.6[b]
Choice Flanks	60.1	49.6[b]	55.1	49.9[b]
50-50 Trim/Kid	57.5	52.0[b]	56.7	50.3[b]
50-50 Brisket/Kid	56.6	47.4[b]	57.3	48.9[b]

a = Analysis of variance was conducted only on percent moisture in cooked patties.

b = means in the same row and column for percent moisture cooked with different superscripts are significantly different (P 0.05).

TABLE 6. Means for percent fat raw and cooked patties incorporating fat at four different levels

	FAT LEVEL							
	Percent Chemically Determined Fat							
	12%		18%		24%		30%	
	Raw	Cooked	Raw	Cooked	Raw	Cooked	Raw	Cooked
Choice Plates	17.2	16.4	20.7	18.8	24.8	20.9	29.5	24.6

TABLE 7. Chemical means for percent moisture raw and cooked patties incorporating fat at four different levels.

	FAT LEVEL							
	Percent Moisture							
	16%		20%		24%		30%	
	Raw	Cooked	Raw	Cooked	Raw	Cooked	Raw	Cooked
Choice Plates	63.9	52.6	61.3	51.0	58.6	52.0	55.8	51.4

TABLE 8. Palatability ratings for patties incorporating fat at four different levels.

	FAT LEVEL			
Parameter[a]	16%	20%	24%	30%
Tenderness	4.9^{b}	$5.2^{b,c}$	5.5^{c}	5.7^{c}
Juciness	4.5^{b}	5.0^{c}	5.1^{c}	5.6^{d}
Connective Tissue Amount	3.6^{b}	$3.8^{b,c}$	4.2^{d}	$3.9^{c,d}$
Mouth Coating Effect	6.2^{b}	6.2^{b}	6.0^{b}	5.6^{c}
Instron Total Work	65.7^{b}	60.9^{b}	53.5^{c}	50.0^{d}

a = based on 8 point scale: 8 = extremely tender, extremely juicy, no connective tissue amount, no mouth coating effect; 1 = extremely tough, extremely dry, abundant connective tissue amount and very pronounced mouth coating effect.

b,c,d = means in the same row with different superscripts are significantly different ($P < 0.05$).

TABLE 9. Soluble, insoluble, and total collagen (mg/g) in patties incorporating fat at four different levels

	FAT LEVEL			
	16%	20%	24%	30%
Soluble Collagen (mg/g)	1.00	1.13	.72	1.02
Insoluble Collagen (mg/g)	11.92	12.91	9.30	11.93
Total Collagen (mg/g)	12.92	14.04	10.02	12.95

TABLE 10. Change in fat and moisture content of patties from the raw to cooked state

	FAT LEVEL			
	16%	20%	24%	30%
Change in Percent Fat[a]	0.8	1.9	3.9	4.9
Change in Percent Moisture[b]	11.3	10.3	6.6	4.4
Total Change	12.1	12.2	10.5	9.3

a = Percent fat raw-Percent fat cooked.

b = Percent moisture raw-Percent moisture cooked.

PHASE VI - PART 3-STORAGE

Objective: To access the effects of storage on palatability of ground beef formulated from five different fat sources: 1) Choice plates; 2) Choice trimmings; 3) Choice flanks; 4) 50% Choice trimmings with 50% kidney fat and; 5) 50% brisket fat with 50% kidney fat (Part 1) and four levels of fat (16, 20, 24, and 30%) (Part 2).

EFFECTS OF VARIOUS PERIODS OF FROZEN STORAGE ON PALATABILITY AND CHEMICAL VALUES OF GROUND BEEF PATTIES

INTRODUCTION

The ground beef treatments discussed under Phase VI Parts I and II, were reevaluated by the sensory taste panel at 3, 6 and 9 months. In addition, TBA values were also determined at 3, 6 and 9 months.

RESULTS AND DISCUSSION OF STORAGE FOR PART I, FAT SOURCES

In general, if ground beef has a TBA value of 2.00 or greater a sensory panel should be able to detect rancidity in the product. As time of storage increases, TBA numbers should increase, reflecting increased rancidity due to prolonged storage. It can be seen from Table 1, that TBA values decreased over time, this can be attributed to either further breakdown to free fatty acids or the perhaps inappropriate procedure of Tarladgis (1960).

Table 2, reveals that as time increased ground beef flavor intensity decreased. This is a result of the increase in detectable off-flavors, mainly rancidity, as time increased (data still being analyzed). In general, storage of ground beef patties formulated from various fat sources, did not affect tenderness, juiciness, connective tissue amount, degree of doneness, or the percent cooking loss (Tables 3 - 7).

CONCLUSION

The 9 month storage of ground beef patties formulated from Choice plates, Choice trimmings, Choice flank, 50-50 Choice trimmings/kidney fat

or 50-50 brisket fat/kidney fat, did not generally increase or decrease sensory panel scores for tenderness, juiciness and detectible connective tissue amount. Cooking parameters of % cooking loss and degree of doneness were generally not affected by storage. The major problem associated with storage was the general decrease in ground beef flavor intensity after 3 months and the increase in off-flavors detected by the panel. If the development of off-flavor could be curtailed ground beef could be stored up to 9 months without generally affecting other palatability traits of ground beef. In general fat source did not affect the palatability or cooking characteristics of stored ground beef.

RESULTS AND DISCUSSION OF PART II, FAT LEVEL

Table 8, shows the TBA values for ground beef, formulated to possess fat levels of 16, 20, 24 and 30% over a 9 month storage period. Again, TBA values decreased instead of increasing as would be expected (refer to results and discussion Part I). In general, ground beef flavor intensity decreased as time increased (table 9). The difference in ground beef flavor intensity between fat levels was small (0.4 maximum). The general decrease in flavor intensity can be related to the increased frequency of off-flavors, predominantly rancidity, as time increased (data still being analyzed). Scores for tenderness and juiciness (Tables 10 and 11) respectively showed a slight tendency to decrease with prolonged freezer storage. The fat level of ground beef did tend to affect the tenderness and juiciness scores within each time frame. However, the sources at 0 month were similar to those noted at 9 months. For example, patties made at 16% fat received a mean tenderness score of 4.9 at 0 month, the lowest of all four scores, and it remained the lowest for each time period (5.2 at 3 month., 4.9 at 6 months

and 4.6 at 9 months - Table 10). In gneral, detectable connective tissue amount was not affected by time, however fat level did affect sensory panel scores for connective tissue amount. Again, the differences in connective tissue amount due to fat level established at 0 month remained approximately the same at 3, 6 and 9 months (Table 12). As a whole the degree of doneness and % cooking loss were not affected by the length of storage (Tables 13 and 14).

CONCLUSIONS

The 9 months storage of ground beef patties containing 16, 20, 24 or 30% fat resulted in an increased incidence of off-flavors, reduced tenderness and juiciness scores. The effects of various fat levels noted at 0 months remained about the same at all successive time intervals. In summary ground beef can be formulated with either Choice plates, Choice flanks, Choice trimmings, 50% Choice trimmings with 50% kidney fat or, 50% brisket fat with 50% kidney fat without affecting the quality of ground beef. Ground beef should be formulated to 20% fat or more to maximize palatability attributes and not stored over 3 months to avoid development of off-flavors.

TABLE 1. TBA number values time for Part 1 - Fat Sources.

Fat Source	STORAGE TIME 0 Months		3 Months		6 Months		9 Months	
	Fat Level		Fat Level		Fat Level		Fat Level	
	24%	30%	24%	30%	24%	30%	24%	30%
Choice Plates	2.37	2.19	.78	.62	.84	.68	.58	.64
Choice Trimmings	1.92	1.47	1.46	.93	1.16	.60	.79	.79
Choice Flanks	.71	1.10	.99	.95	.53	.70	.62	.50
Trim/Kid[a]	1.07	1.18	1.43	1.36	.63	.57	.64	.75
Brisket/Kid[b]	.97	1.02	.79	1.06	.66	.60	.79	.68

[a] = 50-50 Choice trimmings/kidney fat.

[b] = 50-50 Brisket fat/kidney fat.

TABLE 2. Ground beef flavor intensity scores over time for Part 1 - Fat Source.

	STORAGE TIME							
Fat Source	0 Months		3 Months		6 Months		9 Months	
	Fat Level		Fat Level		Fat Level		Fat Level	
	24%	30%	24%	30%	24%	30%	24%	30%
Choice Plates	5.3[c]	5.2	5.1	5.2	4.6	4.7	4.6	4.7
Choice Trimmings	5.5	5.4	5.6	5.2	5.4	4.9	5.3	4.9
Choice Flanks	5.2	5.2	5.1	5.2	4.7	4.8	4.5	4.6
Trim/Kid[a]	5.4	5.4	5.3	5.3	5.0	4.9	5.0	5.0
Brisket/Kid[b]	5.3	5.4	5.2	5.4	5.1	4.8	4.9	4.8

[a] = 50-50 Choice trimmings/kidney fat.

[b] = 50-50 Brisket fat/kidney fat.

[c] = based on 8 pt. scale: 8 = extremely intense, 1 = extremely bland.

TABLE 3. Tenderness scores over time for Part 1 - Fat Source.

	STORAGE TIME							
Fat Source	0 Months		3 Months		6 Months		9 Months	
	Fat Level		Fat Level		Fat Level		Fat Level	
	24%	30%	24%	30%	24%	30%	24%	30%
Choice Plates	5.7[c]	5.6	6.1	5.9	5.2	5.5	5.7	5.6
Choice Trimmings	5.8	5.9	5.8	6.2	5.3	5.6	5.7	5.7
Choice Flanks	5.5	5.6	5.7	6.0	5.0	5.6	5.2	5.3
Trim/Kid[a]	5.4	5.8	5.4	6.0	4.9	5.4	5.1	5.3
Brisket/Kid[b]	5.4	5.7	5.7	5.8	5.2	5.5	5.0	5.2

[a] = 50-50 Choice trimmings/kidney fat.

[b] = 50-50 Brisket fat/kidney fat.

[c] = based on 8 pt. scale: 8 = extremely tender, 1 = extremely tough.

TABLE 4. Juiciness scores over time for Part 1 - Fat Sources.

	STORAGE TIME							
Fat Source	0 Months		3 Months		6 Months		9 Months	
	Fat Level		Fat Level		Fat Level		Fat Level	
	24%	30%	24%	30%	24%	30%	24%	30%
Choice Plates	5.2[c]	5.5	5.5	5.8	4.9	5.5	5.2	5.1
Choice Trimmings	5.5	5.6	5.5	5.8	5.2	5.2	5.2	5.4
Choice Flanks	5.2	5.3	5.5	5.8	5.0	5.6	4.9	5.0
Trim/Kid[a]	5.2	5.6	5.4	5.7	5.2	5.5	4.9	5.2
Brisket/Kid[b]	5.1	5.6	5.4	5.7	5.3	5.4	4.9	5.0

[a] = 50-50 Choice trimmings/kidney fat.

[b] = 50-50 Brisket fat/kidney fat.

[c] = based on 8 pt. scale: 8 = extremely juicy, 1 = extremely dry.

TABLE 5. Connective Tissue Amount over time for Part 1 - Fat Sources.

	STORAGE TIME							
Fat Source	0 Months		3 Months		6 Months		9 Months	
	Fat Level		Fat Level		Fat Level		Fat Level	
	24%	30%	24%	30%	24%	30%	24%	30%
Choice Plates	4.8[c]	4.4	5.0	4.8	4.4	4.0	4.7	4.6
Choice Trimmings	4.7	4.9	4.5	4.9	4.2	4.4	4.9	4.9
Choice Flanks	4.4	4.6	4.4	4.7	4.0	4.3	4.2	4.2
Trim/Kid[a]	4.4	4.7	4.5	4.9	3.9	4.0	4.4	4.5
Brisket/Kid[b]	4.5	4.6	4.6	4.5	3.7	3.8	4.1	4.5

[a] = 50-50 Choice trimmings/kidney fat.

[b] = 50-50 Brisket fat/kidney fat.

[c] = based on 8 pt. scale: 8 = none, 1 = abundant.

TABLE 6. Degree of doneness scores over time for Part 1 - Fat Sources.

	STORAGE TIME							
Fat Sources	0 Months		3 Months		6 Months		9 Months	
	Fat Level		Fat Level		Fat Level		Fat Level	
	24%	30%	24%	30%	24%	30%	24%	30%
Choice Plates	2.2[c]	2.1	2.75	2.00	2.00	2.00	2.25	2.08
Choice Trimmings	2.0	2.0	2.00	2.17	2.13	2.00	2.00	2.00
Choice Flanks	2.0	2.0	2.00	2.00	2.00	2.00	2.00	2.00
Trim/Kid[a]	2.2	2.2	2.08	2.42	2.38	2.00	2.00	2.00
Brisket/Kid[b]	2.2	2.2	2.08	2.00	2.00	2.00	2.00	2.00

[a] = 50-50 Choice trimmings/kidney fat.

[b] = 50-50 Brisket fat/kidney fat.

[c] = based on photographic comparison: 8 = rare, 1 = well done.

TABLE 7. % Cooking loss over time for Part 1 - Fat Sources.

	STORAGE TIME							
Fat Sources	0 Months		3 Months		6 Months		9 Months	
	Fat Level		Fat Level		Fat Level		Fat Level	
	24%	30%	24%	30%	24%	30%	24%	30%
Choice Plates	37.96[c]	38.65	34.81	40.58	42.76	42.14	36.76	42.30
Choice Trimmings	38.40	41.54	39.45	41.72	43.66	45.62	43.81	42.00
Choice Flanks	37.56	38.24	36.74	37.46	43.07	41.58	37.69	42.30
Trim/Kid[a]	40.78	40.55	40.20	40.46	43.20	42.79	41.69	43.23
Brisket/Kid[b]	40.01	39.08	37.61	41.35	40.26	42.53	40.11	43.70

[a] = 50-50 Choice trimmings/kidney fat.

[b] = 50-50 Brisket fat/kidney fat.

[c] $= \left(\frac{\text{frozen wt.} - \text{cooked wt.}}{\text{frozen wt.}}\right) \times 100$

TABLE 8. TBA values over time for Part II. Fat Levels.

Fat level	Storage time			
	0 mon.	3 mon.	6 mon.	9 mon.
16%	1.13	1.03	1.07	.71
20%	1.02	1.03	.80	.69
24%	2.37	.78	.84	.58
30%	2.19	.62	.68	.64

TABLE 9. Ground beef flavor intensity scores over time for Part II. Fat Level.

Fat level	Storage time			
	0 mon.	3 mon.	6 mon.	9 mon.
16%	5.0[a]	5.2	4.8	5.0
20%	5.2	5.3	4.9	4.8
24%	5.4	5.6	5.2	4.8
30%	5.1	5.2	5.0	4.6

[a] Based on 8 pt. scale; 8 = extremely intense, 1 = extremely bland

TABLE 10. Tenderness scores over time for Part II. Fat Level.

Fat level	Storage time			
	0 mon.	3 mon.	6 mon.	9 mon.
16%	4.9[a]	5.2	4.9	4.6
20%	5.2	5.3	5.0	4.9
24%	5.5	5.8	5.3	4.8
30%	5.7	5.9	5.3	5.1

[a] Based on 8 pt. scale; 8 = extremely tender, 1 = extremely tough

TABLE 11. Juiciness scores over time for Part II. Fat Level.

Fat level	Storage time			
	0 mon.	3 mon.	6 mon.	9 mon.
16%	4.5[a]	4.7	4.1	3.8
20%	5.0	4.9	4.6	4.7
24%	5.1	5.5	5.1	4.9
30%	5.6	5.5	5.0	5.2

[a] Based on 8 pt. scale; 8 = extremely juicy, 1 = extremely dry

TABLE 12. Connective tissue amount scores over time for Part II. Fat Level.

Fat level	Storage time			
	0 mon.	3 mon.	6 mon.	9 mon.
16%	3.6[a]	4.3	3.7	3.9
20%	3.8	4.4	3.4	4.0
24%	4.2	5.2	4.1	4.3
30%	3.9	4.6	4.0	4.1

a Based on 8 pt. scale; 8 = none, 1 - abundant

TABLE 13. Degree of doneness scores over time for Part II. Fat Level.

Fat level	Storage time			
	0 mon.	3 mon.	6 mon.	9 mon.
16%	2.1[a]	2.2	2.0	2.4
20%	2.5	2.2	2.2	2.0
24%	2.2	2.1	2.0	2.4
30%	2.0	2.0	1.9	2.0

[a] Based on photographic comparison; 8 = rare, 1 = well done

TABLE 14. % Cooking loss over time for Part II. Fat Level.

Fat level	Storage time			
	0 mon.	3 mon.	6 mon.	9 mon.
16%	35.80[a]	36.16	39.30	38.21
20%	36.00	37.81	39.17	37.56
24%	39.60	38.73	43.38	40.98
30%	40.10	40.69	48.01	44.58

[a] $\frac{\text{frozen wt} - \text{cooked wt}}{\text{frozen wt}} \times 100$

PHASE VI - PART 4

SHELF-LIFE OF PARTS 1 & 2

Objective: To evaluate the shelf-life characteristics of ground beef prepared from raw materials varying as to anatomical location and level of fat.

SHELFLIFE CHARACTERISTICS OF GROUND BEEF MANUFACTURED FROM TRIMMINGS VARYING IN ANATOMICAL LOCATION AND LEVEL OF FAT

Introduction

The vast array of processing procedures and types of trimmings for ground beef provides an excellent environment for the growth of bacteria. The grinding and mixing operations used in ground beef processing permits a rather complete distribution of microorganisms into the product. Several studies have shown high bacterial counts in ground beef normally distributed through retail channels (Rogers and McClesky, 1957; Rao, 1970; Duitschaever, et al., 1973; and Law, et al., 1971). However, Emswiler, et al. (1976) found that proper sanitation and refrigeration will permit prolonged shelflife of ground beef.

While many possibilities exist for contaminating beef trimmings intended for ground beef, little information is available as to whether certain anatomical sources of the trimmings and the level of fat in the final product exert an influence on shelflife characteristics.

EXPERIMENTAL

Sources of raw material and procedures for the manufacture of the ground beef have been previously described under the Phase VI report.

Grab samples for microbiological analyses were aseptically taken from each treatment following product mixing just prior to the final grind. Samples

(25 g) were blended for 2 min. with 225 ml of sterile Butterfield's phosphate buffer. Serial dilutions of the samples were plated in duplicate on 3 sets of plate count agar (Difco Laboratories, Detroit, MI). Plates were incubated at 20°C for 3 days prior to enumeration.

Following the final grind, 454 g samples were wrapped in retail film wrap and stored at 3°C under 90 foot candles of incandescent light. The lights were turned on over the product for 12 hours each day for the 3-day duration of the shelflife study.

Each day a trained three-member panel evaluated the packaged samples for color, amount of surface discoloration and lean and fat distribution. On the third and final day of the storage period, the panel opened the packages and scored the degree of off-odor in the product. The scoring systems for these shelflife characteristics are presented in Table 1.

RESULTS AND DISCUSSIONS

Generally a two-three log increase in bacterial numbers occurred between zero and three days of retail display (Table 3). At the time of initial processing, formulations of Utility chucks-Choice trimmings-Kidney fat and Utility chucks-Kidney fat-Brisket fat had higher mean bacterial counts than other formulations when processed to possess 24% fat. This difference was also observed following three days of display. However, formulations containing kidney and brisket fat were generally lower than most of the other formulations when processed to possess 30% fat regardless of length of storage. No explanation is apparent at this time to explain this result. The 30% formulation level would have more brisket and kidney fat than the 24% level. Brisket fat has more water and kidney fat contains more saturated fatty acids than the other fat which might exert subtle changes in product composition that could affect bacterial numbers.

The distribution of lean and fat was not affected by formulation, level of fat and days of storage (Table 4). There was a tendency for the distribution patterns to be more even at the lower levels of fat, but these differences were nonsignificant ($P > .05$). While kidney fat is certainly a much whiter fat than brisket fat, the evaluation team did not find any visible differences in the distribution of these sources of fat in the final ground product.

The mean values for product color by level of fat with days of storage is depected in Table 5. This interaction effect was nonsignificant ($P > .05$). However, when averaged across storage level, each level of fat differed ($P < .05$) in color score from all other levels. A linear effect was shown in that as fat level increased, lighter color scores were assigned. Certainly, the dilution of the darker lean with increasing fat explains this result. In addition, formulations containing kidney and brisket fat received darker color scores than product incorporating Choice flanks (3.66,3.48 vs 5.76). Also scores assigned following three days of display were darker than the panel values assigned at zero and one day of display (3.44 vs 4.98,4.73).

The interaction effect of storage time with level of fat also proved nonsignificant ($P > .05$) for surface discoloration (Table 6). Level of fat and source of formulation trimmings were not influential on surface discoloration scores. As expected, a significantly ($P < .05$) greater amount of discoloration occurred over the three-day storage period (0 day = 7.30, 1 day = 6.46, 2 day = 5.54, 3 day = 3.93).

While source of formulation materials did not affect the presence of off-odor in the samples, higher levels of fat tended to have higher frequencies of off-odors (Table 7). This trend was significant ($P < .05$) between the 30 and 12 percent fat levels. Since much of the off-odor is a result of bacterial spoilage, lipolytic organisms were possibly quite prevalent in the microbial population of the samples. The significant relationship between off-color and

bacterial counts is shown in Table 8. Likewise samples displaying considerable surface discoloration also had higher bacterial counts. Since much of the discoloration was a change from red to brown and green pigments, the color scores were also highly correlated to surface discoloration.

Storage time appeared to exert more of an influence on shelf-life characteristics than source of product trimmings and level of fat. However, formulations containing kidney and brisket fat had higher bacterial counts when formulated to 24% fat and were darker in color at the completion of the shelf-life study. Higher incidences of off-odor were associated with higher levels of fat in the product.

TABLE 1. Scoring systems for shelf-life study.

Surface Discoloration for Lean and Fat	Lean and Fat Distribution	Color	Off Odor
8 - 0% Discoloration	8 - Very Uniform	8 - Light Grayish Red	4 - No Off Odor
7 - 1-10% Discoloration	7 - Uniform	7 - Very Light Cherry Red	3 - Slight Off Odor
6 - 11-25% Discoloration	6 - Moderately Uniform	6 - Moderately Light Cherry Red	2 - Moderate Off Odor
5 - 26-50% Discoloration	5 - Slightly Uniform	5 - Cherry Red	1 - Extreme Off Odor
4 - 51-75% Discoloration	4 - Slightly Uneven	4 - Slightly Dark Red	
3 - 76-90% Discoloration	3 - Moderately Uneven	3 - Moderately Dark Red	
2 - 91-99% Discoloration	2 - Uneven	2 - Dark Red	
1 - 100% Brown or Green	1 - Very Uneven	1 - Very Dark Red	

TABLE 2. Experimental Design

Formulation Combinations	Levels of Fat	Days of Evaluation Under Retail Display
Utility Chucks - Choice Flanks	12	0
Utility Chucks - Choice Plates	18	1
Utility Chucks - Choice Trimmings	24	2
Utility Chucks - Choice Trimmings-Kidney Fat	30	3
Utility Chucks - Kidney Fat-Brisket Fat		

TABLE 3. Bacterial counts according to ground beef formulation, level of fat and days of storage[a].

FORMULATION	DAYS OF STORAGE 0, LEVEL OF FAT 24	DAYS OF STORAGE 0, LEVEL OF FAT 30	DAYS OF STORAGE 3, LEVEL OF FAT 24	DAYS OF STORAGE 3, LEVEL OF FAT 30
Utility Chucks - Choice Flanks	5.5^{b}	6.0^{c}	8.2^{bc}	7.8^{ce}
Utility Chucks - Choice Plates	5.3^{b}	5.6^{b}	8.0^{b}	7.7^{e}
Utility Chucks - Choice Trimmings	6.0^{c}	5.4^{b}	8.4^{cd}	8.2^{bc}
Utility Chucks - Choice Trimmings-Kidney Fat	7.1^{d}	4.9^{e}	8.9^{d}	7.4^{ef}
Utility Chucks - Kidney fat Brisket Fat	7.0^{d}	5.3^{b}	8.8^{d}	7.2^{f}

[a] mean bacterial counts ($\log_{10}$) per g

[bcdef] means in the same row and column bearing different superscripts are significantly ($P < .05$) different.

TABLE 4. Lean and fat distribution scores as influenced by level of fat and days of storage[a].

Level of Fat, %	Days of Storage			
	0	1	2	3
12	6.40	5.92	5.83	5.94
18	5.61	5.71	5.62	5.64
24	5.54	5.49	5.37	5.24
30	4.83	5.04	4.63	4.78

[a] Scoring system is given in Table 1.

TABLE 5. Color scores as influenced by level of fat and days of storage[a].

Level of Fat, %	Days of Storage			
	0	1	2	3
12	3.01	2.58	2.58	2.44
18	3.79	3.62	3.29	2.85
24	4.76	4.40	4.01	3.15
30	5.19	5.06	4.63	3.73

[a] Scoring system is given in Table 1.

TABLE 6. Surface discoloration scores as influenced by level of fat and days of storage[a].

Level of Fat, %	Days of Storage 0	1	2	3
12	7.29	5.46	4.83	3.71
18	6.76	5.79	5.54	4.86
24	7.17	6.37	5.30	3.57
30	7.42	6.55	5.77	4.29

[a] Scoring system is given in Table 1.

TABLE 7. Off-odor scores as influenced by level of fat[a].

Level of Fat, %			
12	18	24	30
3.72[a]	2.85[ab]	2.53[ab]	2.29[b]

[a] Scoring system is given in Table 1.

TABLE 8. Correlations among shelf-life indicators.

	Color	Surface Discoloration	Lean & Fat Distribu.	Off-Odor
Bacterial Counts	-.43*	-.81**	.01	-.52*
Color	1.00	.76**	-.34	-.02
Surface Discoloration		1.00	-.06	.28
Lean and Fat Distribution			1.00	-.18

* P < .05

** P < .01

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APPENDIX

(Related Research from the

Meat Science Research Laboratory)

Addition of Soy Protein Fiber, Peanut Meal and Mechanically Deboned Beef to Ground Beef

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Running Head: Ground Beef Palatability

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INTRODUCTION

Sufficient animal protein is available to supply the nation's protein requirement, but, socio-economic circumstances may cause an uneven distribution among the population (Bird, 1974). Also, even in an affluent society such as ours, questions arise concerning the waste of useful products. Therefore, much attention has recently been given to methods of recovering and utilizing various kinds of proteins in ground and comminuted meat products.

Bird (1974) estimated that by 1980 about two million pounds of meat will be replaced by various plant proteins. Most agree that soy protein is and will remain the most widely used of these plant protein additives for ground beef production. Obviously, one of the most important factors affecting this usage is palatability. Soy protein from 2 to 30% was tested for palatability and variables such as family income and its effect upon consumer acceptance were considered (Mize, 1968; Twigg et al., 1977). These previous studies showed that addition of various soy proteins to ground beef is feasible in terms of consumer acceptance. Tenderness was improved with the addition of soy (Mize, 1968; Huffman and Powell, 1970; Twigg et al., 1977; Cross et al., 1975) and other sensory panel parameters were minimally affected. Color problems and flatulence factors, however, have been associated with soy protein. Also, the high carbohydrate content of soy leads to severe bacterial spoilage. A new commercial process has been devised to remove most of these carbohydrates. In this process the soy flour is acidified (to the isoelectric pH) and the precipitate is collected and pressed into a fiber. The resulting product, termed

"soy protein fiber" is 90% protein with a pH of 5.2. The structure of the soy additive as "fiber" is hoped to increase the textural desirability of food products. Substitution of the soy protein fiber for beef has not been evaluated for its effect on the textural qualities of ground beef.

Research in the area of plant protein addition to ground beef is not entirely limited to soy. McWatters (1977) found that patties containing steam-heated peanut meal were similar in palatability to all beef patties and to patties containing a soy protein additive. Commercial advocates of "flaked peanut meal" maintain that in contrast to the traditional soy additives, peanut meal has enough fiber to add texture to food products. Also, peanut meal does not possess flatulence factors and sustains a long shelf-life. Processing methods for flaking of peanuts are presently being developed.

Mechanical deboning of beef has been suggested as a means of reducing protein waste by recovering meat and marrow from bones (Field, 1976; Fried, 1976). Many large packing facilities at one time were equipped with mechanical deboning machines. Cross et al. (1977) reported that sensory panel members preferred ground beef patties containing up to 20% added mechanically deboned beef to the controls.

Addition of soy protein, peanut meal, and mechanically deboned beef increases the tenderness of ground beef patties as indicated in the previous studies cited. Excessive substitution of an additive for beef, however, may cause undesirable mushiness. The objective of this study was to compare the effects of soy protein fiber (SPF),

peanut meal (PM), and mechanically deboned beef (MDB) upon ground beef texture. Combination of the MDB with SPF and with PM were also tested.

EXPERIMENTAL

Product Formulation

Two hundred kg of hand deboned beef from USDA Choice grade chucks were coarse ground through a 2.54 cm plate and thoroughly mixed in a Hobart Mixer-Grinder (model 4346). This procedure insured that all treatments were of an identical lean source. The coarse ground beef was then randomly divided into 15 batches weighing approximately 13 kg each. The formulations listed in Table 1 were prepared by adding in the appropriate levels of MDB, SPF, and PM to 14 of the batches on a percent weight basis. The remaining batch (treatment 1, Table 1) did not have any amount of MDB, SPF, or PM added to it and thus served as a control of 100% beef. The PM was dehydrated Nutrex precooked peanut flakes and was added on a hydrated basis (1 part PM to 1 part water). The SPF was supplied by the Ralston Purina Company and was added on a dry weight basis. Combinations of MDB with SPF and MDB with PM were also tested. None of the treatment groups required the combination of SPF with PM. After the appropriate levels of MDB and/or PM or SPF were added, the batches were separately mixed for 1 min; ground through a 1.9 cm plate; mixed for 1 min; and finally ground through a .32 cm plate. Patties weighing 114 g and .95 cm in thickness were prepared in a Hollymatic patty machine (model 200). Patties were frozen and stored at -20 C until needed for sensory and chemical analysis.

Ground Beef Palatability

Trained Panel

An eight member sensory panel, trained by the procedures of Cross *et al*. (1978), evaluated samples from each treatment in a total of 15 sessions; six samples were evaluated per session. The control was replicated 11 times and the treated groups either 5 or 6 times as determined by a random numbers table. The parameters evaluated were: tenderness (8 = extremely tender, 1 = extremely tough); juiciness (8 = extremely juicy, 1 = extremely dry); and cohesiveness (8 = extremely cohesive--mushy, 1 = extremely uncohesive--coarse). Due to the particle size and texture of MDB, addition of large amounts to ground beef could lead to a "mushy" product (Cross, *et al*., 1977). This concern also applies to some plant proteins (Cross *et al*., 1975). The sensory panel was trained to evaluate those possible differences as cohesiveness. Patties served to the sensory panel were cooked from the frozen state on electric Farberware grills (275 C) for five minutes per side.

Cooking Losses and Shear

Cooking loss from the frozen to the cooked state was determined by weighing ten patties per treatment before and after cooking. Each of the 10 patties were pictorially scored for degree of doneness (color photographs with 1 = well done and 8 = rare) by a well trained observer. The patties were then sectioned into four 2.54 cm squares and the resulting 40 sections were measured for maximum shear and area under peak curve using the Instron single blade technique of Cross *et al*. (1978).

Ground Beef Palatability

Chemical Analysis

Moisture per cent was determined by weighing four 3 g samples before and after drying in a 102 C oven for 24 hours. Fat percent was determined by weighing the four 3 g samples before and after a 12-hour fat extraction in diethyl ether. Fat levels were expected to vary due to the addition of the extra protein sources.

Statistical Analysis

Sensory panel, degree of doneness, percent fat and percent moisture mean values for each of the 15 treatment formulations were tested for significant differences by the analysis of variance (ANOVA) followed by Duncan's multiple range test (Duncan, 1955). In the Results and Discussion, the results from this statistical procedure for sensory panel data will always refer to the comparison between the means of the specific treatment formulations listed.

In addition, the ANOVA procedure of Klotz and Teng (1977) was performed to test the individual effects of each additive. This ANOVA process determines if a significant response is given by adding varying levels of additive. Discussion based on this type of statistical analysis will not associate an additive with a percent level of addition but will refer to the general effects or "overall" response given by the sensory panel over the range in which it was added.

RESULTS AND DISCUSSION

Tenderness

Mean values from the trained sensory panel for tenderness are listed in Table 2. In agreement with Cross *et al*. (1977), ratings for tenderness were significantly ($P < .05$) higher for patties containing

30% MDB than the mean value of the control product. Patties containing 20 or 30% MDB did not differ in tenderness. The mean value of 5.1 for the control treatment approached an unacceptable level of tenderness. Overall, the addition of peanut meal (PM) significantly ($P < .01$) improved tenderness, but patties containing 5% PM were similar to the control. Patties with 10% PM were rated significantly ($P < .05$) more tender than the control. Overall, the addition of soy protein fiber (SPF) to the formulation significantly ($P < .001$) decreased tenderness. Patties containing SPF at both the 5% and 10% levels were rated less tender than the control and patties containing either MDB or PM alone. Those differences often were large enough to be important.

The addition of MDB at both the 20% and 30% levels improved the tenderness of patties containing 5% or 10% SPF. This improvement was significant ($P < .05$) for 10% SPF plus 30% MDB _vs_ 10% SPF alone. The improvement in tenderness also was significant between 10% SPF and 30% MDB _vs_ 10% SPF and 20% MDB. Tenderness for patties containing 5% PM was significantly improved with the addition of either 20% or 30% MDB, but this was not the case for the 10% PM level. However, the combination of 10% PM plus 30% MDB yielded the highest mean tenderness value of any treatment.

Our data from tenderness evaluation suggest that: (1) addition of MDB and/or PM improved tenderness, (2) SPF decreased tenderness, and (3) the addition of MDB to SPF formulations tended to offset the negative effect of SPF. Those conclusions are supported by ratings of the trained sensory panel and by the Instron measurements of shear force and area.

Ground Beef Palatability

Juiciness

MDB did not have a significant effect on juiciness (Table 3). Mean values for patties containing 0% (control), 20% and 30% MDB did not differ. Furthermore, addition of PM did not significantly affect sensory panel juiciness scores. Mean values for juiciness did not differ between 0% (control), 5% and 10% PM. Addition of SPF to the ground beef patties significantly (P <.001) decreased sensory panel juiciness scores. Patties with 10% SPF were rated significantly lower in juiciness than the patties with 0% (control) or 5% SPF. The negative effect of SPF on juiciness might be attributed to the low pH of the SPF additive. Combining SPF with MDB generally improved sensory panel juiciness over that of SPF added alone.

Cohesiveness

Similar to sensory panel tenderness results, MDB was significantly (P <.05) linear in its effect on sensory panel cohesiveness (Table 3). Patties containing 30% MDB differed significantly (P <.05) from the control in cohesiveness. In agreement with Cross et al. (1977), this result may indicate that addition of MDB at 30% or higher may lead to mushy ground beef. The increased tenderness achieved by adding MDB may be attributed to its tendency to produce a mushy texture due to its small particle size. This occurrence may not be detectable up to 20% added MDB. Patties containing 20% MDB were similar to both 30% MDB and the all-beef control. The addition of SPF alone did not significantly affect cohesiveness. The mean values for patties containing 5% or 10% SPF were similar to the mean value of the control. Therefore, it could be concluded that addition of SPF does not increase the coarseness of

ground beef although its addition yields a less tender product. Combination of SPF with 30% MDB increased the cohesiveness of the ground beef patties. Patties containing 10% PM had significantly (P <.05) larger mean values for cohesiveness than those containing 5% PM or the control. This may indicate that similar to MDB, substitution with PM at high levels may yield a mushy texture. Combinations of PM and MDB resulted in the highest mean values of all treatments for cohesiveness.

Cooking Properties

Addition of higher levels of MDB and SPF alone resulted in lower ratings for degree of doneness (Table 4). These decreases were significant (P <.05) between MDB at 30% vs MDB at 20% and the 0% control. Similarly, SPF at 10% was significantly lower than 5% SPF and the control. Patties with PM at 10%, however, were significantly higher (less well done) than PM at 5%. Although data were not treated statistically, formulations containing SPF appear to have sustained less cooking loss than formulations without SPF (Table 5).

Conclusions

Conclusions based on these data are: (1) addition of MDB or PM alone increased the tenderness and cohesiveness of ground beef patties but did not affect juiciness, (2) addition of SPF decreased tenderness and juiciness but did not affect the cohesiveness of ground beef patties.

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Table 1. Product formulation

Treatment	% Beef	% MDB[a]	% SPF[b]	% PM[c]
1	100			
2	80	20		
3	70	30		
4	95		5	
5	90		10	
6	95			5
7	90			10
8	75	20	5	
9	70	20	10	
10	75	20		5
11	70	20		10
12	65	30	5	
13	60	30	10	
14	65	30		5
15	60	30		10

[a]MDB = mechanically deboned beef

[b]SPF = structured protein fiber

[c]PM = peanut meal

Table 2. Sensory and physical measurements of tenderness subjected to Duncan's Multiple Range test (Duncan, 1955).

Formulation	Descriptive panel tenderness	Instron force (newtons)
Control (100% beef)	5.1^{e-i}	111.15^{b}
20% MDB	5.5^{c-f}	93.95^{d}
30% MDB	6.2^{a-c}	71.08^{f}
5% SPF	4.8^{fg}	119.85^{a}
10% SPF	3.9^{h}	124.53^{a}
5% PM	5.2^{d-g}	104.60^{bc}
10% PM	6.0^{a-d}	102.43^{c}
20% MDB; 5% SPF	5.2^{d-g}	97.05^{cd}
20% MDB; 10% SPF	4.6^{gh}	85.45^{e}
20% MDB; 5% PM	6.1^{a-c}	77.23^{ef}
20% MDB; 10% PM	6.0^{a-d}	79.00^{ef}
30% MDB; 5% SPF	5.6^{c-f}	74.88^{f}
30% MDB; 10% SPF	5.6^{b-e}	73.08^{f}
30% MDB; 5% PM	6.4^{ab}	72.05^{f}
30% MDB; 10% PM	6.6^{a}	62.48^{g}

[a-i]Means in the same column bearing an identical letter in the superscript do not differ (P<.05).

Table 3. Mean values for juciness and cohesiveness subjected to Duncan's Multiple Range test (Duncan, 1955).

Formulation	Descriptive panel juiciness	Descriptive panel cohesiveness
Control (100% beef)	5.8[a-d]	4.8[f]
20% MDB	5.6[a-e]	5.2[c-f]
30% MDB	6.0[a-c]	5.6[a-d]
5% SPF	5.4[de]	5.1[d-f]
10% SPF	4.7[f]	4.8[f]
5% PM	5.6[a-e]	4.7[f]
10% PM	5.6[a-e]	5.4[b-e]
20% MDB; 5% SPF	5.4[c-e]	5.2[c-f]
20% MDB; 10% SPF	5.0[ef]	5.0[ef]
20% MDB; 5% PM	6.1[ab]	5.8[ab]
20% MDB; 10% PM	5.5[b-e]	5.7[a-c]
30% MDB; 5% SPF	5.4[c-e]	5.5[a-d]
30% MDB; 10% SPF	5.7[a-d]	5.4[b-e]
30% MDB; 5% PM	6.2[a]	6.1[a]
30% MDB; 10% PM	5.7[a-d]	5.9[ab]

[a-f]Means in the same column bearing an identical letter in the supercript do not differ (P<.05).

Table 4. Mean Values for degrees of doneness, cooking losses and chemical analysis of uncooked patties

Formulations	Degree of doneness[a]	Cooking losses (%)	Fat (%)	Moisture (%)
Control (100% beef)	3.2[gh]	35.4	25.5[c]	53.0[h]
20% MDB	3.3[h]	34.7	29.5[fg]	51.5
30% MDB	2.4[c]	34.5	32.4[h]	48.6[c]
5% SPF	3.1[g]	30.9	26.7[de]	53.3[hi]
10% SPF	2.7[de]	30.6	23.9[b]	56.7[j]
5% PM	2.8[ef]	34.2	32.2[h]	43.7[b]
10% PM	3.9[i]	32.2	26.1[cd]	54.4[i]
20% MDB; 5% SPF	3.1[g]	30.9	29.8[fg]	50.3[d-g]
20% MDB; 10% SPF	2.9[f]	30.2	29.1[f]	50.0[d-f]
20% MDB; 5% PM	2.4[c]	31.4	26.0[cd]	55.7[j]
20% MDB; 10% PM	2.7[de]	35.0	30.3[g]	49.5[c-e]
30% MDB; 5% SPF	2.2[b]	31.2	29.9[fg]	51.0[fg]
30% MDB; 10% SPF	2.2[b]	29.4	31.9[h]	44.0[b]
30% MDB; 5% PM	2.6[d]	32.1	27.6[e]	53.8[hi]
30% MDB; 10% PM	2.7[de]	33.3	32.4[h]	49.0[cd]

[a]Scored pictorially with 1 = well done and 8 = rare.

[b-h]Means in the same column bearing an identical superscript do not differ (P<.05).

EFFECTS OF PRECOOKING BEEF PATTIES ON PALATABILITY, COOKING PROPERTIES, AND STORAGE STABILITY

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Running Head: Precooked Beef Patties

Introduction

There has been increased interest in the meat industry to produce precooked meat items for use by the institutional trade. Several elementary and secondary schools in the U.S. are using precooked, frozen beef patties rather than frozen, raw beef patties. Some advantages cited in favor of precooking are reduced cooking time prior to serving and fewer cooking losses. There is almost no published research data to support these statements. Soy added to meat may reduce the stale or warmed-over flavor in reheated meat because certain vegetable extracts are effective antioxidants. Sato et al. (1973) found that adding one of several cereal protein products to ground-meat loaves prevented rancidity. Bowers and Engler (1975) added soy protein to raw patties that were subsequently either cooked or precooked, frozen, and reheated and found the reheated patties to be less juicy regardless of the amount of soy in the formulation. The soy-containing patties that were not precooked also had less meaty aroma and flavor than the all beef controls (Bowers and Engler, 1975).

To our knowledge, no one has evaluated the palatability of patties precooked with commercial equipment. We, therefore, undertook to evaluate the effects of precooking under commercial conditions on palatability and cooking properties of patties containing various levels of soy protein. Different spice and soy levels were included in the design to simulate current school lunch/industry practices and provide a product that could vary in cooking and palatability traits.

Experimental

Seven ground beef formulations were prepared at two locations as outlined in Table 1. All raw materials were selected on the same days at each location. U.S. Utility square-cut chucks were used as the primary lean source; fat from U.S. Good and Choice plates was used to adjust the fat content. Minimum batch size of each formulation was 45 kg, and two batches of each formulation were prepared at both locations. Each batch was prepared from different chucks and plates.

<u>Comminution</u>:

<u>Location A</u>. All material was chopped in a commercial chopper for 1 min and sampled for fat analysis. After a 1-min mix, 10 grab samples (0.60 kg. each) were analyzed for fat with the Anyl-ray instrument. Fat content ranged between 28.5 to 29.7% for two batches, and the formulation was mixed for 1 min. Hydrated soy flour (1.5 water to 1 soy) and soy protein concentrate (see Table 1) were added to the formulation, and the batch was mixed again for 1 min. The product was passed through a 0.32-cm plate for the final grind. The ground beef mixture was formed into 75g patties with a formax patty machine. The patties were chilled with CO_2 to an internal temperature of about 0 to 2°C. They were then either frozen or precooked.

<u>Location B</u>. All raw material was passed through a 1.90-cm breaker plate, mixed for 1 min. and sampled for fat analysis. Fat content was determined with a Honeywell fat analyzer. Fat content was 28.5 to 29.5%, respectively, for the two batches.

The mixtures were formualted and the patties prepared as described for location A.

Precooking Methods

Location A. Patties were broiled in a custom-made gas broiler to an internal temperature of approximately 50 to 55°C. The design of the cooking apparatus was such that the patty moved along a belt and was heated from both sides. The time from beginning of cooking until the product reached the freezer was approximately 4 min. Patties then passed through a liquid nitrogen tunnel for 5 to 6 min and were chilled to an internal temperature of about -5°C.

Location B. Patties were broiled in a custom-made gas broiler to an internal temperature of approximately 50 to 55°C. The heat source was from both directions as in location A. The oven was 13 m long and the time from beginning of cooking until the product reached the freezer was approximately 4 min. Patties were frozen in a NH_3 carousel to an internal temperature of approximately -10°C.

Frozen patties from each location (raw and precooked) were stored at -10°C for two days until shipment via air (-10°C) to the Meat Science Research Laboratory at Beltsville, Maryland, where they were stored at -20°C for analysis.

Cooking Losses

Fifty raw patties from each batch/formulation/location combination were randomly selected for weighing before and after the precooking/freezing treatment. Patties were weighed to the

nearest 28.0g. The weights of 15 raw, frozen patties and 15 precooked, frozen patties were determined; each was reweighed after cooking at the Meat Science Research Laboratory, and total cooking losses were determined.

Cooking Procedures

Frozen raw and frozen precooked patties were cooked in an electric oven preheated for 30 min at 225°C. Patties were placed four to a pan, two pans per oven, and roasted at 200°C for 13 min. The patties were not turned during cooking. Preliminary cooking trials revealed that frozen patties whether precooked or raw, required approximately the same amount of time to reach an internal temperature of 55°C. Internal temperature was measured with iron/constantan thermocouples connected to a Honeywell recorder.

Frozen, precooked patties were also cooked in a General Electric model 500 microwave oven. Four patties were placed on a glass plate and cooked for 2 min. Then the plate was rotated one-quarter turn and the patties were cooked 2 more min.

Sample Preparation and Presentation to Panel

Samples were served warm to the panelists (within 2 min after removing from the oven). Each patty was quartered, and two pieces from each sample randomly allotted to each panelist. Samples were placed in nonwaxed paper cups and served to the panelist one cup at a time. To prevent cooling during serving, the paper cups were placed on heated sand for no more than 2 to 3 min. Panelists were served distilled water at room temperature so that they could rinse their mouths between samples.

Trained Descriptive Attribute Panel

An eight-member panel, trained according to Cross et al. (1978), evaluated samples from each of the three cooking treatments in a total of 24 sessions; and six samples were evaluated at each session. The trained panel evaluated each sample for tenderness, fragmentation, juiciness, detectable connective tissue, and flavor intensity on the basis that 8 = extremely tender, juicy, no connective tissue, and intense flavor; and 1 = extremely tough, dry, an abundant amount of connective tissue, and bland flavor. The panel also subjectively evaluated the samples for flavor acceptability in order to detect those samples that were intense but unacceptable in flavor from those with intense acceptable flavor. Only four of the seven formulations (Table 1) were presented to the sensory panel.

Instron Shear

Ten patties from each treatment were sheared with single blade device attached to the Instron as described by Cross et al. (1978). Each patty was allowed to cool 2 hr and sectioned into four 2.54-cm squares. Each square was sheared once.

Oxidative Rancidity

Five patties from each treatment were randomly selected, frozen in liquid nitrogen, and powdered in a high-speed blender. Rancidity, as TBA values, was determined by the procedures of Tarladgis et al. (1964).

Statistical Analysis

The experimental design was a 4x3x2 factorial with incomplete blocks (formulation; cooking method and location) and each contrast (comparison) was estimatable in at least two of the six replications. Mean separation was performed according to Scheffe (1959). In designing the study, we were concerned that the precooking location interactions might confound the reheating methods location interactions. If location is found to have significant effects, all location interactions will vary accordingly; however, cooking method and formulation can still be studied if they are averaged over location. Consequently, when an interaction involving location was significant at the $P<0.05$ level, we constructed a second ANOVA table (not shown) such that each sum of squares involving location was pooled with the error sum of squares into a residual sum of squares term. This enabled us to test the remaining mean squares and to gain information about main effects averaged over location. The estimate of pure error from the first ANOVA table (not shown) was used in each means analysis only when all interactions were nonsignificant ($P<0.05$); otherwise, the pooled residual mean square from the second ANOVA table was used.

Results and Discussion

Mean squares associated with the main effects of formulation (except for juiciness) and cooking method were highly significant and quite large compared to each significant interaction mean square (data not shown). Consequently, real differences in formulation and/or cooking methods could be expected. This was confirmed with the second ANOVA (data not shown), which also showed no significant interactions between formulation and cooking method.

Sensory panel and Instron maximum shear force results are presented in Tables 2 through 8. Mean separation was calculated across all formulations and the three cooking methods. Mean values for tenderness are presented in Table 2. The addition of soy to the formulation significantly increased the panel ratings for tenderness. The all-beef formulation (no soy proteins) was rated "slightly tough" by the panel. Experience indicates that a rating of less than 5 (8-point scale) by a trained panel usually indicates that the product would be rated as "unacceptable" by a consumer panel. Cross et al. (1976b), Huffman and Powell (1970) and Twigg et al. (1975) have also reported increased tenderness with increasing levels of soy. U.S. Utility chuck is a common raw material for use in ground beef -- including that accepted by U.S.D.A. school lunch purchase programs. Cross et al. (1976a) reported that ground meat produced from U.S. Utility or lower grade meat was unacceptably tough, due primarily to large amounts of "tough" connective tissue. Likely, the addition of soy protein diluted the connective tissue in the final product. Although panel tenderness ratings for patties prepared at location A were higher, formulations were ranked in the same order at each location.

Patties that were cooked from the frozen, raw state were significantly more tender than patties that were precooked and then reheated. The differences were large enough to be important. Differences between cooking methods were also significant within each formualtion.

Mean values for Instron maximum shear force by formulation, cooking method, and location are presented in Table 3. There was a significant formulation/cooking method interaction but in view of the highly significant effect of cooking method, we concluded that differences exist between cooking methods. Panel and maximum shear force evaluations of tenderness agreed closely. All beef (no soy protein) patties were significantly ($P < 0.05$) tougher than patties containing high levels of soy protein. Precooked patties were significantly tougher than patties cooked from the raw state.

Panel ratings for ease of fragmentation (Table 4) followed trends similar to panel evaluations of tenderness (Table 2) and maximum shear force (Table 3). As it did for tenderness, the addition of soy protein increased the ratings for ease of fragmentation. Precooking with subsequent reheating adversely affected texture. Patties that were reheated with the microwave oven were rated significantly lower than were those cooked by the other two methods.

Panel ratings for connective tissue are presented in Table 5. The addition of soy protein to the formulation tended to offset the adverse effects of connective tissue. Cross et al. (1977) reported that the addition of mechanically deboned beef had a similar effect on ground beef produced from U.S. Utility grade meat. Cooking method significantly affected panel ratings for connective tissue. Patties cooked from the raw, frozen state had less panel-detectable connective tissue than reheated patties.

The addition of soy protein to the formulation did not significantly affect panel ratings for juiciness (Table 6) but cooking method had a

pronounced effect. Precooked, reheated patties were rated significantly lower than patties cooked from the raw state, and the differences were large enough to be of practical concern. There were differences between locations; but, as with previous palatability attributes (Tables 2-5), the rankings were identical between locations.

Tables 7 and 8 present data for panel ratings of flavor intensity and flavor acceptability. Acceptability ratings are usually used only with untrained consumer panels but were used in this study to "flag" possible off-flavors. In general, the panel objected to the level of pepper and spices in the formulations. Many panelists commented that the flavor was not necessarily undesirable but just not that of ground beef. This comment was reflected in the intensity ratings which were all above 6.0 (Table 7). No trends could be established with regard to soy, spice level, or formulation. An exception was the all beef formulation (No. 1); it received the highest ratings for intensity and the lowest for acceptability (Tables 7 and 8). Formulation 1 was the only one containing salt and black pepper. Huffman et al. (1978) reported that low levels of salt usually enhanced the flavor of ground beef. Likely, the black pepper was the main contributor to the unfavorable ratings; but to be certain, additional research will be necessary. Cooking method significantly affected ratings for flavor intensity but not for flavor acceptability (Tables 7 and 8). As mentioned, the spice level was likely so high that any differences due to cooking method were masked.

Mean ratings for degree of doneness are presented in Table 9. The formulation x location x cooking method interaction was highly significant (P <0.005). After adjustment for location, the formulation x cooking method interaction (data not shown) was also highly significant (P <0.005). Results for formulation and cooking method were significant (P <0.05); however, we do not know whether the significance was due to the formulation x cooking method interaction or real differences in formulation and/or cooking method. Patties that were not precooked tended to be rated less well done than patties that were precooked and reheated. Reheating by roasting or with microwave seemed to have little effect on degree of doneness.

Mean TBA values by cooking method are presented in Table 10. The formulation x location interaction was significant (data not shown). We then determined whether the formulations differed significantly in TBA values given the significant interaction. The F value for formulation was significant (P <0.002) and indicated that formulation 1 generally had higher TBA values than the remaining formulations. Cooking method had no significant effect on TBA values. By the end of 2 months storage, most patties had reached a level of oxidative rancidity that could be normally detected by a trained panel.

One of the often cited advantages for precooking and reheating frozen patties is reduced cooking loss as compared to that of non-precooked patties. Cooking loss can best be evaluated on the basis of the total loss from raw patty to the final cooked patty. Total loss can be determined from Table 11, which presents the stepwise losses. Cooking losses for patties that were precooked and reheated

were from 10 to 15 percentage points greater than those for the non-precooked patties. As expected, cooking loss was the highest for the all-beef patty.

Conclusions

The level of soy protein in the formulation and cooking method significantly affected palatability. The primary objective of this study was to evaluate the effects of precooking beef patties on ultimate palatability. Various levels of soy protein in the formulation were included in the experimental design only so that we could evaluate the effects of cooking methods on patties widely different in palatability. Patties that were precooked, frozen, and reheated were tougher and drier, and lost more weight during processing than those not precooked. The all-beef patty had unacceptably high TBA values regardless of location or cooking method. Our study indicates that there is little advantage to precooking beef patties.

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Mention of brand names does not imply endorsement by the U.S. Government.

Table 1. Patty Formulation

Formulation	Beef	Salt	Black Pepper	Spices	Soy Flour	Soy Concen.	Water
	%	%	%	%	%	%	%
1	98.55	1.00	0.05	----	----	----	----
2	89.25	----	----	0.75	4.00		6.00
3	78.50	----	----	1.50	8.00		12.00
4	68.00	----	----	2.00	12.00		18.00
5	87.75	----	----	2.25	2.00	1.40	6.60
6	77.00	----	----	3.00	5.00	2.15	12.85
7	67.50	----	----	2.00	7.00	3.00	20.50

Table 2. Mean panel tenderness ratings for each level of formulation, formulation by cooking method, and formulation by location

		Tenderness Rating[a]				
		Cooking method			Location	
Formulation[b]	Formulation average	Precook and roast reheat	Precook and microwave reheat	Raw and roast	1	2
1	4.64[e]	4.26	4.33	5.32	4.88	4.39
2	5.07[d]	4.70	4.42	6.10	5.32	4.82
3	5.57[c]	5.31	4.99	6.40	5.82	5.31
4	5.80[c]	5.49	5.29	6.62	5.90	5.69
Average	5.27	4.94[2]	4.76[2]	6.11[1]	5.49	5.05

[a]8 = extremely tender and 1 = extremely tough.
[b]Refer to Table 1 for composition of each formulation.
[cde]Means in the same column with different superscripts differ significantly ($P < .05$).
[1,2]Means in the same row with different superscripts differ significantly ($P < .05$).

Table 3. Instron maximum shear force means (kg) by formulation, formulation cooking method, and formulation location

		Maximum shear force Cooking method			Location	
Formulation[a]	Formulation average	Precook and roast reheat	Precook and microwave reheat	Raw and roast	1	2
1	5.11[bc]	5.46	5.62	4.26	4.00	6.22
2	5.78[b]	6.32	5.61	5.50	4.75	6.66
3	5.00[bc]	5.63	4.96	4.29	3.97	5.90
4	4.60[c]	5.06	4.64	4.11	4.72	4.49
5	4.85[c]	4.66	4.78	4.11	4.13	5.58
6	4.51[c]	4.96	4.70	3.87	4.15	4.87
7	4.40[c]	4.50	4.72	3.97	4.20	4.59
Average	4.89	5.24[1]	5.15[1]	4.34[2]	4.28	5.51

[a]Refer to table 1 for composition of each formulation.
[bcd]Means in the same column with different superscripts differ significantly ($P < .05$).
[1,2]Means in the same row with different superscripts differ significantly ($P < .05$).

Table 4. Mean panel ease of fragmentation ratings by formulation, formulation cooking method, and formulation location

Formulation[b]	Formulation average	Fragmentation rating[a]: Cooking method: Precook and roast reheat	Precook and microwave reheat	Raw and roast	Location: 1	2
1	4.95[e]	4.71	4.71	5.42	5.20	4.69
2	5.19[de]	4.96	4.67	5.96	5.40	4.99
3	5.44[cd]	5.24	4.82	6.26	5.64	5.24
4	5.65[c]	5.37	5.18	6.39	5.78	5.51
Average	5.31	5.07[2]	4.84[3]	6.01[1]	5.50	5.11

[a]8 = extremely easy and 1 = extremely difficult.
[b]Refer to table 1 for composition of each formulation.
[cde]Means in the same column with different superscripts differ significantly ($P < .05$).
[1,2,3]Means in the same row with different superscripts differ significantly ($P < .05$).

Table 5. Mean panel connective tissue ratings by formulation, formulation cooking method, and formulation location

		Connective tissue rating[a]				
		Cooking method			Location	
Formulation[b]	Formulation average	Precook and roast reheat	Precook and microwave reheat	Raw and roast	1	2
1	4.52[f]	4.40	4.33	4.83	4.76	4.28
2	4.85[e]	4.57	4.50	5.47	4.98	4.72
3	5.27[d]	5.06	5.00	5.74	5.37	5.16
4	5.57[c]	5.38	5.35	5.97	5.67	5.46
Average	5.05	4.85[2]	4.80[2]	5.50[1]	5.20	4.91

[a]8 = no detectable connective tissue and 1 = abundant
[b]Refer to table 1 for composition of each formulation
[cdef]Means in the same column with different superscripts differ significantly ($P < .05$).
[1,2]Means in the same row with different superscripts differ significantly ($P < .05$).

Table 6. Mean panel juiciness ratings by formulation, formulation cooking method, and formulation location

		Juiciness ratings[a]				
		Cooking method			Location	
Formulation[b]	Formulation average	Precook and roast reheat	Precook and microwave reheat	Raw and roast	1	2
1	5.32[c]	4.86	5.05	6.05	5.78	4.86
2	5.45[c]	5.05	5.05	5.96	5.57	5.33
3	5.52[c]	5.14	4.98	6.44	5.80	5.23
4	5.39[c]	5.07	4.84	6.26	5.42	5.36
Average	5.42	5.03[2]	4.98[2]	6.25[1]	5.64	5.20

[a]8 = extremely juicy and 1 = extremely dry.
[b]Refer to table 1 for composition of each formulation.
[c]Means among different formulations were not significantly different (P <.05).
[1,2]Means in the same row with different superscripts are significantly different.

Table 7. Mean panel flavor intensity ratings by formulation, formulation cooking method, and formulation location

	Flavor intensity[a]					
		Cooking method			Location	
Formulation[b]	Formulation average	Precook and roast reheat	Precook and microwave reheat	Raw and roast	1	2
1	6.71[c]	6.79	6.82	6.52	6.56	6.86
2	6.12[d]	6.14	6.40	5.82	6.02	6.22
3	6.23[de]	6.20	6.38	6.12	6.27	6.19
4	6.41[e]	6.34	6.55	6.34	6.45	6.37
Average	6.37	6.37[2]	6.54[1]	6.20[3]	6.32	6.41

8 = extremely intense and 1 = extremely bland.
Refer to table 1 for composition of each formulation.
deMeans in the same column with different superscripts differ significantly (P <.05).
,2,3Means in the same row with different superscripts differ significantly (P <.05).

Table 8. Mean panel flavor acceptability ratings by formulation, formulation cooking method, and formulation location

Formulation[b]	Formulation average	Cooking method: Precook and roast reheat	Cooking method: Precook and microwave reheat	Cooking method: Raw and roast	Location: 1	Location: 2
1	3.26[d]	3.23	3.18	3.38	2.93	3.60
2	4.21[c]	4.29	4.04	4.29	4.25	4.16
3	4.08[c]	4.23	3.75	4.27	4.12	4.05
4	3.90[c]	4.03	3.61	4.06	3.98	3.82
Average	3.86	3.95[1]	3.65[1]	4.00[1]	3.82	3.91

Flavor acceptability[a]

[a]8 = extremely acceptable and 1 = extremely unacceptable.
[b]Refer to table 1 for composition of each formulation.
[d]Means in the same column with different superscripts differ significantly ($P < .05$).
[1]Means among cooking method not significantly different ($P < .05$).

Table 9. Mean degree of doneness ratings by formulation, formulation cooking method, and formulation location

	Degree of doneness[a]					
		Cooking method			Location	
Formulation[b]	Formulation average	Precook and roast heat	Precook and microwave reheat	Raw and roast	1	2
1	1.8	1.6	1.4	2.6	2.3	1.3
2	1.9	1.5	1.4	2.6	1.9	1.9
3	1.9	1.7	1.8	2.3	2.1	1.8
4	1.8	1.8	1.6	2.1	1.8	1.9
5	2.0	2.0	1.8	2.3	2.3	1.8
6	2.1	2.1	1.9	2.4	2.3	2.0
7	2.2	1.9	2.1	2.5	2.4	2.0
Average	2.0	1.8	1.7	2.4	2.2	1.8

[a]8 = rare and 1 = well done (color photographs).
[b]Refer to table 1 for composition for each formulation.

Table 10. Mean TBA values by cooking method and storage item

	TBA values					
	Precooked			Raw		
Formulation[a]	Initial	Two months	Four months	Initial	Two months	Four months
1	3.26	6.97	4.48	2.38	5.32	11.56
2	0.91	1.83	2.87	1.05	5.39	5.54
3	0.72	1.37	2.01	0.56	1.04	1.64
4	0.69	0.91	0.88	0.57	1.16	0.79
5	1.13	2.08	4.05	0.90	1.72	2.11
6	0.91	1.68	3.01	0.82	1.88	2.38
7	1.11	1.86	2.84	0.66	1.48	1.72
Average	1.25	2.38	2.88	0.99	2.57	3.68

[a]Refer to table 1 for composition for each formulation.

Table 11. Cooking losses for each formulation by cooking method

Formulation[a]	Cooking loss % Raw to precooked A	Precook to roast reheat B	Precook to microwave reheat C	Raw to roast D
1	21.74	17.18	18.78	28.22
2	22.95	14.99	16.95	26.96
3	14.80	13.46	13.96	15.38
4	13.00	11.10	12.63	13.11
5	18.19	16.90	16.69	17.65
6	13.43	13.62	14.23	16.07
7	13.45	16.01	14.98	14.50
Average	16.79	14.71	15.46	19.11

[a]Refer to table 1 for composition for each formulation.

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EFFECT OF QUALITY GRADE AND CUT FORMULATION ON THE PALATABILITY OF GROUND BEEF PATTIES

ABSTRACT

Chucks and short plates were selected from 25 carcasses representing the middle third of each of five U.S. quality grades. Beef patties were prepared from chucks and short plates individually and in combination. Taste tests were conducted on the samples in order to study the effect of quality grade and cut formulation on palatability of the cooked product. Over the range of carcasses graded from Prime to Cutter, taste panel subjective evaluations of tenderness, connective tissue amount and overall acceptability decreased significantly. Patties from Prime, Choice and Good carcasses were rated as acceptable in all palatability traits (5.0 or above on a 9-point scale) whereas patties from Utility and Cutter grades were rated 4.0 or less in tenderness, connective tissue amount and overall acceptability. Differences in juiciness and flavor were not substantially affected by quality grade. Patties formulated from chucks were rated more desirable in tenderness, flavor, connective tissue amount and overall acceptability than patties from short plates or short plate-chuck combinations. Differences in palatability due to quality grade were larger than those due to cuts.

INTRODUCTION

SINCE 1970, the U.S. Department of Agriculture has purchased over 415 million pounds of ground beef for distribution to schools. This product was purchased under the Schedule AA–USDA Specification for Frozen Ground Beef. This specification requires that beef and calf be the only ingredients and these shall be derived from fresh chilled beef or calf carcasses, sides and/or cuts of the U.S. Utility grade or higher for beef and U.S. Standard or higher for calf. The specification also states that at least 50% of the total weight of the beef (or calf) shall be from any one or any combination of primal cuts (major) and the remaining 50% or less may be from any one or any combination of rough (minor) cuts. Limited research information is available as to the acceptability of ground beef from various U.S. quality grades and to the effect of major versus minor cuts on palatability. Fruin and Van Duyne (1961) reported palatability differences in ground beef prepared from chucks and rounds from U.S. Commercial or Standard carcasses. Quality grade had no significant effect on palatability whereas panelists preferred ground beef from chucks to that from rounds. Information is needed as to the effect of wide ranges in quality grade and various combinations of major and minor cuts on palatability of cooked ground beef. Perhaps beef of a lower U.S. quality grade could be utilized to produce acceptable ground beef. Likewise it may be possible to use a higher proportion of rough cuts in the formulation thus producing a more economical product. Therefore, the study objective was to determine how ground beef formulations of varying quality grades and cuts would affect cooked ground beef palatability.

EXPERIMENTAL

FIVE CARCASSES were selected to represent the middle third of each of five USDA quality grades (Prime, Choice, Good, Utility and Cutter). Each carcass was selected from the previous day's slaughter. From each carcass one chuck and both short plates were removed, boned and shipped about 10 miles in a refrigerated truck to the commercial Research Laboratory. To meat of the Utility and Cutter grades enough subcutaneous and kidney fat from other carcasses of those grades was added to approximate 24% fat content in the ground beef.

Sixteen combinations of ground beef were prepared as outlined in Table 1. The lean and fat were ground through a 0.64 cm plate, mechanically mixed for 2 min and ground through a 0.32 cm plate for the final grind. Prior to the final grind, the mixture was sampled for fat analysis by the Modified-Babcock procedure. Fat content was standardized at 24 ± 2% by the addition of appropriate amounts of fat or lean. Fat content was controlled, as much as possible, since the aim of the project was to study the effect of differences in grade and cut on palatability. In preparing the major vs. minor cut combinations for treatments 11–16 (Table 1) each chuck and plate was ground separately through the 0.64 cm plate, combined in equal amounts of fat or lean from chucks and plates, mixed and finally ground through a 0.32 cm plate. The ground meat was formed into 75g patties 10 cm in diameter using a Hollymatic Patty Machine. During processing, the product internal temperature did not exceed 10°C. All patties were placed in boxes (4.5 kg to a box), frozen in a blast freezer (–30°C), and shipped to Beltsville, Md., via air freight.

Cooking

Patties were roasted from the frozen state in a 200°C oven for 9 min, quartered, and served as hot as possible to the panelists. A subsample of 10 patties per treatment was cooked to obtain weights for drip, evaporative and total cooking loss.

Panel selection and training

Male and female panelists were selected from the scientific and ancillary staff of the Agricultural Research Center. Selection was based on assessments of repeatability on duplicate samples and consistency of

Table 1—Sample designation

Sample no.	Grade/Cut	
	Name	Symbol
1	Prime/chuck	P/C
2	Choice/chuck	C/C
3	Good/chuck	G/C
4	Utility/chuck	U/C
5	Cutter/chuck	Cu/C
6	Prime/plate	P/P
7	Choice/plate	C/P
8	Good/plate	G/P
9	Utility/plate	U/P
10	Cutter/plate	Cu/P
11	Prime/combination[a]	P/CP
12	Choice/combination	C/CP
13	Good/combination	G/CP
14	Utility/combination	U/CP
15	Cutter/combination	Cu/CP
16	Choice and Cutter/ combination	C/Cu/CP

[a] Combination consisted of chuck and plate in equal proportions

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ratings in relation to the group. Triangle tests were conducted over a period of 3 wk (total = 15) and 16 panelists were selected on the basis of these data. After each training session, discussions were held with the panelists in order to achieve unanimity in the interpretation of the scoring system. Panelists evaluated the samples under red lights in booths. If each panelist had been present for every session, there would have been an equal number (9) of evaluations by each panelist on every ground beef sample combination. The "ideal" panel situation would have resulted in each sample combination receiving 144 evaluations. In actuality, panelist attendance was not perfect. Three panelists had fewer than 50 evaluations while the remaining 13 averaged 120 evaluations out of a possible 144. To avoid problems in statistical analysis created by a wide disparity between the number of evaluations made by the panelists, the data from those three members were eliminated.

A trained 13-member panel rated each pattie for tenderness and juiciness by using a 9-point scale (9 = extremely tender or juicy and 1 = extremely tough or dry). Tenderness and juiciness were evaluated during the first 5–10 chews. The amount of connective tissue residue remaining at the end of mastication was rated by using a 9-point scale (9 = none and 1 = very abundant amount). Due to the study design, flavor was rated on the basis of "desirability" rather than "intensity." Since off-flavors might be rated as "intense" an "intensity" scoring system could not differentiate between "intense-desirable" and "intense-undesirable" flavors. The taste panel evaluations were conducted over a time span of eight 3-day periods. Panelists evaluated six ground beef samples each day so that during each three-day period all sixteen sample combinations were tested. In addition, two sample combinations were repeated during each session. The daily assignment of sample combinations was presented to the panel nine times during the course of the study.

Statistical techniques

Panel palatability evaluations are discrete in nature (i.e., integer valued from 1 to 9). Nonparametric statistical methods are the most appropriate type of statistical technique to use on taste panel data. These methods do not assume that the data have any specific type of distribution. In particular, nonparametric methods do not require that the data have a normal distribution. On the other hand, it is reasonable to assume that results of cooking loss analyses are normally distributed. That assumption, if not entirely true, is at least sufficiently true to be satisfactory for most practical applications.

Friedman's Test (1937) which was used to analyze the taste panel data, is analogous to the two-way analysis of variance procedure. It is used to test the null hypothesis that all combinations have the same mean effects against the alternative hypothesis, that the combination mean effects are not all equal. The method of McDonald and Thompson (1967) uses the rank sums computed from Friedman's Test for the nonparametric multiple comparison of the combination means. "Experimentwise error rates" are used rather than "significance levels" when discussing this multiple comparison procedure. The "experimentwise error rate" is defined as "the ratio of the number of experiments in which at least one difference between means is falsely declared significant to the total number of experiments conducted over a long period time."

RESULTS & DISCUSSION

RESULTS of Friedman's Test indicated that the mean effects of the 16 sample combinations were significantly different at the 5% level of significance for each of the five palatability characteristics. Table 2 shows the results of nonparametric multiple comparisons of the 16 sample combinations for all five palatability characteristics. The combinations are arranged in order of decreasing values of the rank sums, and their means followed approximately the same order.

The nonparametric multiple comparisons shown in Table 2 enable the use of statistical techniques to objectively investigate the "closeness" of the mean values of the individual sample combinations. Ground beef formulated from Prime or Choice carcasses was more acceptable in all palatability traits (except juiciness) than ground beef prepared from Utility or Cutter carcasses. If a taste panel rating of 5.0 or above is arbitrarily designated as acceptable and 4.9 and below is unacceptable in palatability, then ground beef prepared from Prime, Choice and Good chucks or Prime and Choice plates was rated as "acceptable" in all five taste panel traits. Ground beef prepared from Good plates and Utility and Cutter chucks and plates was usually below 5.0 (unacceptable).

Lean and fat from Choice and Cutter chucks and plates were combined to determine whether the addition of Choice meat would offset the low palatability ratings of ground beef

Table 2–Nonparametric multiple comparisons for palatability traits

Tenderness			Juiciness			Flavor			Connective tissue amount			Overall acceptability		
Combination	Mean	Rank sum[a,b]	Combination	Mean	Rank sum[a,b]	Combination	Mean	Rank sum[a,b]	Combination	Mean	Rank sum[a,b]	Combination	Mean	Rank sum[a,b]
C/C	6.6	196	C/C	5.5	154.5	P/CP	5.9	165.0	C/C	6.7	198.0	C/C	6.4	191.5
P/C	6.3	189.5	G/C	5.4	141.5	C/C	6.0	163.5	P/C	6.6	197.0	P/C	5.7	167.0
G/C	6.0	171.5	P/P	5.3	140.0	P/P	5.8	160.0	P/P	6.2	173.0	P/CP	5.8	167.0
P/P	5.9	169.0	C/P	5.2	132.0	C/CP	5.8	152.0	G/C	6.1	164.0	P/P	5.7	161.5
P/CP	5.6	148.5	G/CP	5.2	130.0	G/C	5.6	146.5	P/CP	5.8	152.0	G/C	5.8	159.5
C/CP	5.2	133.0	Cu/P	5.2	125.0	C/P	5.7	146.5	C/P	5.6	138.5	C/P	5.7	154.0
C/P	5.1	124.5	C/CP	5.2	122.0	P/C	5.5	138.0	C/CP	5.5	134.0	C/CP	5.4	149.0
G/CP	4.8	114.5	P/CP	5.1	115.5	G/CP	5.1	104.5	G/P	5.3	125.0	G/CP	4.9	113.0
G/P	4.6	99.5	C&Cu/CP	5.0	108.5	U/P	4.9	104.0	G/CP	5.0	109.0	G/P	4.5	94.5
C&Cu/CP	4.3	80.5	P/C	5.0	107.5	C&Cu/CP	5.2	98.0	U/C	4.3	33.0	U/P	4.3	92.0
U/C	4.2	77.5	G/P	5.1	104.5	U/C	4.8	91.5	U/P	4.0	78.5	C&Cu/CP	4.4	82.5
U/P	4.4	74.5	U/P	5.0	99.0	Cu/C	4.6	78.0	C&Cu/CP	4.0	73.0	U/C	4.1	74.5
Cu/CP	3.7	62.5	Cu/C	4.9	89.0	U/CP	4.5	73.5	Cu/C	3.2	50.0	Cu/C	3.6	55.0
Cu/C	3.9	58.0	Cu/CP	4.9	81.0	G/P	4.6	60.5	U/CP	3.1	42.5	U/CP	3.4	41.5
Cu/P	3.4	41.5	U/C	4.8	80.0	Cu/CP	4.1	48.5	Cu/CP	2.6	27.5	Cu/CP	3.0	39.5
U/CP	3.4	27.0	U/CP	4.3	38.0	Cu/P	4.1	38.0	Cu/P	2.5	23.0	Cu/P	3.0	26.0

[a] Vertical lines connect all sample combinations which are NOT significantly different for an experimentwise error rate of 5%.

[b] A rank sum difference of at least 83 is required for significance for an experimentwise error rate of 5%.

Table 3—Nonparametric multiple comparisons for palatability traits by overall quality grade and cut

Tenderness			Juiciness			Flavor			Connective tissue amount			Overall acceptability		
Grade	Mean	Rank[a,b] sum	Grade	Mean	Rank[a,b] sum	Grade	Mean	Rank[a,b] sum	Grade	Mean	Rank[a,b] sum	Grade	Mean	Rank[a,b] sum
Prime	5.9	61	Choice	5.3	53	Prime	5.7	56	Prime	6.2	62	Prime	5.7	60
Choice	5.6	54	Good	5.2	47	Choice	5.8	54	Choice	5.9	53	Choice	5.8	57
Good	5.1	41	Prime	5.1	42	Good	5.1	33	Good	5.5	41	Good	5.0	37
Utility	4.0	21	Cutter	5.0	37	Utility	4.7	31.5	Utility	3.8	26	Utility	3.9	26
Cutter	3.7	18	Utility	4.7	16	Cutter	4.3	20.5	Cutter	2.8	13	Cutter	3.2	15

[a] Vertical lines connect all sample combinations which are NOT significantly different for an experimentwise error rate of 5%.
[b] A rank sum difference of at least 23 is required for significance for an experimentwise error rate of 5%.

Table 4—Nonparametric multiple comparisons for palatability traits by cut

Tenderness			Juiciness			Flavor			Connective tissue amount			Overall acceptability		
Cut	Mean	Rank[a,b] sum	Cut	Mean	Rank[a,b] sum	Cut	Mean	Rank[a,b] sum	Cut	Mean	Rank[a,b] sum	Cut	Mean	Rank[a,b] sum
Chuck	5.4	39	Plate	5.2	30.5	Chuck	5.3	35	Chuck	5.4	38	Chuck	5.1	37
Plate	4.7	21	Chuck	5.1	25.5	Plate	5.0	22	Plate	4.8	26	Plate	4.7	23
Combination	4.5	18	Combination	4.9	22.0	Combination	5.1	21	Combination	4.4	14	Combination	4.5	18

[a] Vertical lines connect all sample combinations which are NOT significantly different for an experimentwise error rate of 5%.
[b] A rank sum difference of at least 12 is required for significance for an experimentwise error rate of 5%.

from Cutter carcasses. The addition of Choice grade meat (C&Cu/CP) increased the palatability ratings in all five traits; however, all mean ratings remained below 5.0 except those for flavor and juiciness. Panelists rated tenderness and connective tissue amount lowest of all the palatability traits. Probably the amount of connective tissue from lower grade carcasses significantly influenced the rating for tenderness and overall acceptability. This hypothesis is supported by the magnitude of the simple correlation coefficients between tenderness and connective tissue amount ($r = 0.74$) and overall acceptability and connective tissue amount ($r = 0.71$).

For chuck, mean scores for all palatability traits, except juiciness, were similar for Prime, Choice and Good meat. Choice, however, consistently scored highest. In contrast, the palatability ratings for plates or any combination containing plates tended to steadily decrease as quality grade decreased.

Nonparametric multiple comparisons by overall grade for all five palatability characteristics are presented in Table 3. Except for juiciness, the panelists' evaluations coincide with our "a priori" knowledge of the palatability characteristics of quality grades; that is, the mean values for Prime and Choice were very similar and consistently higher than those for Utility and Cutter. The mean values for the Good grade were usually intermediate. Differences in mean values between grades were not as pronounced for juiciness as for other palatability traits. In general, however, these results tend to confirm that USDA quality grades provide meaningful assessments of the quality of ground beef as measured by the other four palatability characteristics. Palatability ratings for the amount of connective tissue were less than 4.0 for Utility and Cutter ground beef. Possibly that trait accounts for the low scores in overall acceptability.

Nonparametric multiple comparisons for cuts are presented in Table 4. Except for juiciness, the mean palatability values were consistently and significantly higher for chuck than for plate. The mean value for the combination was consistently lower than the mean values for chuck or plate (except for flavor). Apparently the addition of chuck to the formulation did not offset the adverse palatability of the plate. Juiciness did not differ significantly between means of cuts. Analysis of variance for drip loss, evaporation loss and total loss (not shown in table) indicated that the mean values of the sixteen combinations were not significantly different.

CONCLUSIONS

DIFFERENCES in palatability of ground beef patties between grades were significant and large enough to be important. Ground beef from Prime and Choice carcasses was consistently rated higher than that from Utility and Cutter; Good grade ground beef was usually intermediate. Ground beef from chucks was rated higher in palatability, except for juiciness, than that from plates or chuck-plate combinations. Apparently the addition of chuck in equal proportion with plate was not sufficient to bring the "combination" palatability up to an "acceptable" level in the lower grades. These data support the USDA's regulations requiring minimum quality grades. Further work is needed to evaluate additional quality grade and cut combinations to determine the most economical formulation that would yield an acceptable product.

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Mention of specific trade names and companies is for identification purposes and does not imply endorsement by the U.S. Government.

DESTRUCTION OF BACTERIA IN BEEF PATTIES BY COOKING[1,2]

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SUMMARY

The destruction of bacteria in beef patties during cooking was evaluated to define the number of microbes that might be ingested when patties were cooked to different degrees of doneness. Commercially fabricated, 85-g beef patties from three wholesale distributors were stored frozen at −45 C or refrigerated for 1, 5 and 12 days at 4 C to simulate normal and abused products. Patties were cooked at either 149, 177, 204 or 232 C for a total of 2 to 8 minutes. Viable coliform bacteria were reduced to minimum countable levels (less than 14/g) by cooking at 177 C for 1.5 min on each side. Psychrotrophic bacteria were no longer countable after the patties had been cooked for 4 min per side at any of the temperatures, whereas destruction of aerobic bacteria required heat treatment beyond 4 minutes. The incidence of *Escherichia coli* and *Staphylococcus aureus* was reduced by more than 50% by cooking the beef patties. Reduction of bacterial viability by heating was more readily accomplished in the 12-day patties than in the frozen or 1-day patties.

(Key Words: Bacteria, Beef Patties, Cooking, Destruction of Bacteria.)

INTRODUCTION

Bacterial contamination of steaks and roasts has usually been considered to be a surface phenomenon. During broiling, roasting or frying the heat of cooking destroys most or all viable surface bacteria. For ground beef patties and restructured steaks, however, the possible survival of bacteria in the center of the patty must be considered.

Emswiler *et al.* (1976) cited literature which reported that ground beef may contain extensive bacterial populations. Mueller (1975) indicated that burgers from a vending machine had a mean total aerobic count of 3.1 × 10^5/g, but the count was reduced to 4.0 × 10^4/g by heating the burgers in a microwave oven. During subsequent testing she found that reheating the hamburgers by microwave did not reduce bacterial numbers markedly. Mueller, in further tests, indicated that the total aerobic count was 5.2 × 10^6/g in raw market hamburgers and 5.6 × 10^4/g in fried patties. Cooking conditions were not specified, but the two log reduction from 6 to 4 appeared to be of some importance. Buck *et al.* (1975) reported that raw patties should be cooked for 6 min on each side on a grill at 137 C to reduce total aerobic bacteria from 10^5 – 10^8/g to about 10^2/g; reductions were similar in lactose fermenters and *Escherichia coli*.

Our objective was to determine the influence of time and temperature of grilling on the destruction of bacteria in commercially fabricated beef patties. With the continued interest in the wholesomeness of meat, importance is placed on defining the number of microbes that might be ingested when patties are cooked to varying degrees of doneness. This information may be of particular use to processors who make precooked patties, which may be subsequently abused and permit the growth of *Staphylococcus aureus*.

EXPERIMENTAL PROCEDURE

Fresh, 85-g beef patties were purchased from three wholesale distributors. The patties typically were fabricated of triangle beef (chuck, brisket, plate) from U.S. Good carcasses. The meat was boned and stored at ambient temperature (about 11 C) for 1.5 hr, then ground through a 2.54 cm breaker plate and a .32 cm

[1] Mention of product names does not imply endorsement by the United States Government.

[2] Mr. E. James Koch, Agricultural Research Service, United States Department of Agriculture provided advice and assistance in analyzing the data.

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TABLE 1. INTERNAL TEMPERATURE (°C) OF COOKED BEEF PATTIES[a]

Griddle temperature (°C)	Cooking time[b] (min/side)							
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
149	5.0	10.0	53.5	59.0	63.0	65.0	66.5	69.0
177	29.5	41.0	45.0	58.5	63.0	64.5	67.0	69.0
204	39.5	51.0	61.5	64.5	66.5	70.5	72.0	76.0
232	41.0	59.0	65.0	70.0	72.5	75.0	74.5	78.0

[a]Each value is the mean of two observations.

[b]Cooked from frozen state.

fine plate. One fourth of the patties were frozen and stored at −45 C until cooked. The remainder were stored at 4 C for 1, 5 or 12 days prior to cooking to increase microbial numbers and provide products with different microbial counts.

Beef patties were cooked in duplicate on a Hotpoint (230 watt) griddle at either 149, 177, 204 or 232 C as determined by a surface thermometer. Cooking times were 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 or 4.0 min per side. Frozen patties were cooked unthawed and patties stored at 4 C were removed from refrigeration immediately before cooking. Internal temperatures of cooked patties are shown in table 1. A sterile Ridak Sanitary Paper Gasket (Boonville Manufacturing Corporation, Boonville, NY) was used to circumscribe a cross section of the center of each patty to aid in the removal of an 11-g sample, which was excised with a sterile scalpel and forceps. Each sample from the cooked and raw control patties was blended with 99 ml sterile phosphate buffer in a sterile Mason jar for 2 minutes. Serial dilutions were treated by the procedures described in table 2 for enumerating coliform, total aerobic and psychrotrophic bacteria. We tested for *E. coli* and coagulase positive *Staphylococcus aureus*, but did not count them.

The data, as the logarithms of the mean bacterial counts, were treated by analysis of variance (Snedecor and Cochran, 1972) and the Duncan's Multiple Range Test (Duncan, 1955). To preclude analysis of data with zero values, .1 was added to bacterial counts/gram, before their conversion to logarithms. In tables, where actual bacterial numbers were presented, the .1 was removed from each value.

TABLE 2. MEDIA AND INCUBATION CONDITIONS FOR MICROBIAL DETERMINATIONS

Organism	Media	Incubation Time	Incubation Temp.
Coliforms	Violet Red Bile Agar (BBL)	48 hr	35 C
Coliforms[a]	Lauryl Sulfate Broth (BBL)	24 hr	35 C
Escherichia coli[a]	EC Broth (BBL)	24 hr	45.5 C
	Levine EMB Agar (BBL)	24 hr	35 C
Coagulase positive *Staphylococcus aureus*[a]	Trypticase Soy Broth (BBL) + 9.5% NaCl	48 hr	35 C
	Baird-Parker Agar (Difco)	48 hr	35 C
	Brain Heart Infusion Broth (BBL)	24 hr	35 C
	Coagulase test using Coagulase Plasma EDTA (Difco)	6 hr	37 C
Aerobes[b]	Standard Methods Agar (Difco)	48 hr	35 C
Psychrotrophs	Standard Methods Agar	10 days	5 C

[a]Modified U.S. Department of Agriculture (1974) procedure – only the 10^{-1} dilution was completed.

[b]U.S. Department of Agriculture (1974).

TABLE 3. MEAN BACTERIAL COUNTS PER GRAM OF UNCOOKED BEEF PATTIES FROM THREE MEAT WHOLESALE DISTRIBUTORS[a]

Bacteria	Days stored	Distributor 1	Distributor 2	Distributor 3
Coliforms	Frozen	3.8×10^{fg}	9.4×10^{f}	1.5×10^{g}
	1	2.4×10^{3} cd	5.0×10^{2} e	1.7×10^{3} de
	5	9.2×10^{3} c	1.4×10^{3} de	1.8×10^{5} b
	12	1.8×10^{6} a	1.4×10^{6} a	3.2×10^{5} b
Aerobes	Frozen	2.1×10^{5} ef	3.0×10^{5} def	1.0×10^{5} f
	1	6.2×10^{5} de	5.7×10^{5} de	9.6×10^{5} d
	5	9.6×10^{6} bc	9.6×10^{6} bc	2.7×10^{7} abc
	12	3.2×10^{7} abc	4.2×10^{7} ab	5.8×10^{7} a
Psychrotrophs	Frozen	8.2×10^{5} de	5.4×10^{5} e	3.2×10^{4} f
	1	5.0×10^{6} cd	9.8×10^{5} de	8.3×10^{6} c
	5	3.9×10^{8} ab	6.8×10^{7} b	2.0×10^{8} ab
	12	3.9×10^{8} ab	4.4×10^{8} a	4.1×10^{8} ab

[a]For a given bacterial group, means within a block followed by the same letter are not significantly different ($P<.05$). Each mean is based on four values.

RESULTS AND DISCUSSION

Evaluation of the uncooked beef patties from the three distributors (table 3) showed some significant differences in coliform, aerobic and psychrotrophic bacteria among samples stored for the same time. In the few instances of significance ($P<.05$), the magnitude of the difference was usually less than one log and therefore was of questionable importance. Storage of the patties at 4 C increased bacterial numbers with time, and coliform counts ranged from 10 to 10^6; aerobic counts from 10^5 to 10^7; and psychrotrophic bacterial counts from 10^4 to 10^8. Patties were not stored longer than 12 days because such patties would not normally be presented to consumers.

Time and temperature of cooking consistently had the greatest influence on survival of all bacteria counted (table 4). Temperature × time

TABLE 4. MEAN SQUARES AND THEIR STATISTICAL SIGNIFICANCE OBTAINED FROM ANALYSIS OF VARIANCE OF BACTERIAL NUMBERS OF BEEF PATTIES AFTER COOKING

Source	df	Bacteria: Coliforms	Aerobes	Psychrotrophs
Distributor	2	1.19	34.04	34.53
Batch	3	1.94	1.18	26.12
Day at 4 C	3	1.08	105.57**	34.17
Dist × day	6	4.60	37.93	55.50
Batch × day	9	.95	1.33	11.44
Error B	15	2.41	15.97	29.07
Temperature	3	15.81***	65.64***	69.65***
Time	6	108.50***	266.30***	423.85***
Temp × time	18	1.80***	1.94***	2.26**
Day × temp	9	1.55**	4.86***	4.24***
Day × time	18	3.87***	16.49***	7.91***
Day × temp × time	54	.84**	1.09**	.97
Error	540	.52	.70	1.10

**($P<.01$).

***($P<.001$).

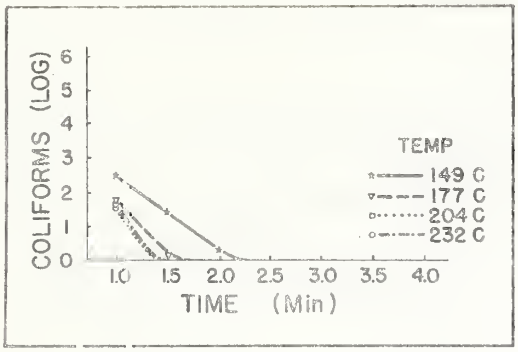

Figure 1. Mean coliform bacteria per gram of beef patty after cooking.

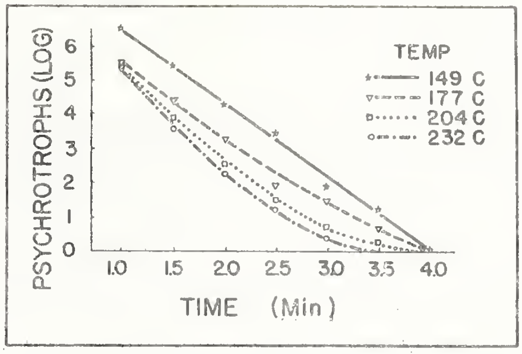

Figure 3. Mean psychrotrophic bacteria per gram of beef patty after cooking.

and the interactions with days affected bacterial counts significantly ($P<.01$). Distributor, batch and interactions with these variables were not significant.

Viable coliforms were reduced to minimum detectable limits by increases in either temperature or time of cooking (figure 1). Heating patties by cooking at 149 C for 2.5 min per side or 177 C for 2 min or 204 C for 1.5 min was adequate for significant ($P<.05$) and relevant decreases in viable coliform bacteria. These data confirm the fact that coliforms are sensitive to heat and suggest that enteric pathogens (*i.e., Salmonella*) also might be destroyed.

The shortest cooking procedure, 1 min per side at 149 C, reduced aerobic bacteria by about 1 log. As temperature and time of cooking were increased, bacterial numbers decreased so that patties cooked at 149 C for 4 min, 177 C for 3.5 min, 204 C for 3 min or more, or at 232 C for 2.5 min or more, contained fewer than 100 bacteria/g (figure 2).

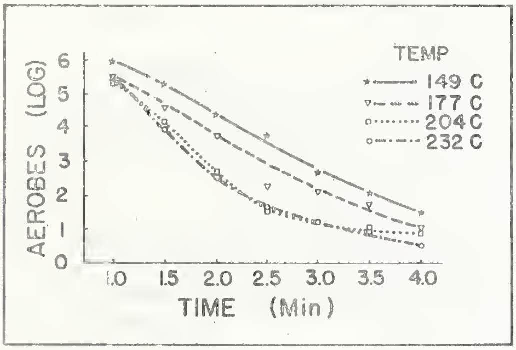

Figure 2. Mean aerobic bacteria per gram of beef patty after cooking.

Buck *et al.* (1975) suggested that patties should be cooked 6 min at 163 C. Those researchers evaluated 100-g patties that measured 87 x 18 mm, whereas we evaluated commercial 85-g patties that measured 108 x 10 mm. Kotula and Rough (1975) reported that commercial 85-g beef patties cooked 4 min per side at 149 C were rated as "well done."

Psychrotrophic bacteria are almost as sensitive to heat as the coliform bacteria (figure 3). Patties cooked by heating at 149 C or 177 C for 4 min per side, or 204 C for 3.5 min, or 232 C for 3 min reduced the bacterial count to about the minimum countable limits. Even cooking patties 2.5 min per side at 177 C or higher effectively reduced counts by about five logs from the initial number in raw patties.

TABLE 5. PERCENTAGE OF RAW AND COOKED BEEF PATTIES CONTAINING *ESCHERICHIA COLI* AND *STAPHYLOCOCCUS AUREUS*

Bacteria		Uncooked (%)	Cooked (%)
E. coli	Frozen	100[a]	53[c]
	1	100[b]	58[d]
	5	100[b]	36[d]
	12	88.1[b]	20[d]
S. aureus	Frozen	100[a]	49[c]
	1	100[b]	34[d]
	5	50[b]	17[d]
	12	25[b]	3[d]

[a]Each mean based on 12 values.

[b]Each mean based on 8 values.

[c]Each mean based on 180 values.

[d]Each mean based on 120 values.

TABLE 6. MEAN BACTERIAL COUNTS OF BEEF PATTIES BEFORE AND AFTER COOKING

Bacteria	Days storage	Treatment[a]	
		Uncooked[b]/g	Cooked[c]/g
Coliforms	Frozen	3.8×10^{d}	.8[a]
	1	1.0×10^{3} c	.7[a]
	5	1.4×10^{4} b	.5[a]
	12	8.1×10^{5} a	.6[a]
Aerobes	Frozen	1.9×10^{5} d	7.7×10^{3} a
	1	7.1×10^{5} c	1.2×10^{3} ab
	5	1.4×10^{7} b	3.9×10^{2} bc
	12	4.5×10^{7} a	1.0×10^{2} c
Psychrotrophs	Frozen	2.2×10^{5} d	1.2×10^{3} a
	1	3.2×10^{6} c	2.3×10^{2} a
	5	1.2×10^{8} b	1.1×10^{2} a
	12	4.1×10^{8} a	2.1×10^{2} a

[a]For a given bacterial group, means within a column having the same letters are not significantly different ($P<.05$) according to Duncan's Multiple Range Test (1955).

[b]Each mean is based on 168 values.

[c]Each mean is based on eight values for well-done patties.

Additional research is needed to determine whether partially cooked meat products, such as the burgers evaluated by Mueller (1975), contain inordinately high numbers of enteric or spoilage bacteria prior to the partial cooking procedure. The influence of composition (fat, water or extenders) on survival of bacteria during cooking should also be evaluated.

The incidence of *E. coli* and *S. aureus* was reduced by more than 50% by cooking the beef patties (table 5). Contrary to expectations, cooking apparently destroyed *E. coli* and *S. aureus* more readily in the 12-day patties than in the frozen and 1-day patties. The response was similar for coliforms, total aerobes, and psychrotrophs (table 6). In each instance, bacterial counts were greatest in the 12-day patties, but the log reduction by cooking was so large, counts were lower for 12-day than for frozen or 1-day cooked patties.

Increasing the temperature or time of cooking effectively reduced counts of all bacterial species evaluated. Increase of temperature, however, may be the procedure of choice because it shortened cooking time. Minimum effective cooking time would be important to fast food outlets, schools, armed forces and to any purveyor responsible for mass feeding.

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CONSUMER ACCEPTANCE OF BEEF PATTIES CONTAINING SOY PROTEIN[1]

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SUMMARY

Beef patties containing hydrated textured soy protein (TSP) or soy concentrate (SC) at 20 or 30% levels were evaluated by a standard consumer panel and by family consumer panels. The standard 52-member panel which evaluated four patties without condiments at each session were able to discern some difference ($P<.05$) in tenderness, flavor, appearance, aroma, juiciness and overall acceptability. All-beef patties and patties containing 20% TSP were rated higher in flavor and overall acceptability than the other patties. One panel of 52 families earning over $10,000 a year could not discern any differences among patties, prepared at home with condiments, in flavor, appearance, aroma and overall acceptability. They also rated all-beef patties less tender than most patties containing soy. Another panel of 52 families earning less than $10,000 per year did not discern any differences among patties. Age of the consumer affected tenderness, juiciness and aroma scores, but sex apparently did not affect any scores. On the basis of acceptability, families earning less than $10,000 per year should provide a good potential market for beef patties containing soy protein.

(Key Words: Beef Patties, Beef-Soy Patties, Consumer Acceptance, Beef Palatability.)

INTRODUCTION

Previous studies on acceptance of beef patties containing soy protein reported the palatability and acceptability of samples, which were cooked uniformly and presented to consumer panelists for evaluation under standard taste panel procedures. Glover (1968), Huffman and Powell (1970), Cross *et al.* (1975) and Kotula *et al.* (1976) presented data from such studies, indicating that beef patties containing up to 20% hydrated textured soy protein would be acceptable to the consumer.

Cross *et al.* (1975) indicated that palatability rating of soy-beef patties for flavor, appearance and overall acceptance were significantly higher by male than by female panelists. They indicated that further research should be carried out to study possible differences in palatability scores due to panelists' age, social, ethnic and economic status. Such information would be important in selection of evaluation panels. Panelists chosen to represent a large segment of potential customers might aid in selecting market areas for the sale of beef patties containing soy protein.

The present study was carried out to determine the reactions of panelists to meat patties that they were allowed to prepare at home by their preferred methods. We also studied the effects of sex, age and economic status on the attitudes of panelists toward all-beef patties that had been extended with soy protein.

EXPERIMENTAL PROCEDURE

Four brands of textured soy protein (TSP) designated A, B, C, D and two brands of soy concentrate (SC) designated E, F were hydrated, 1 to 1.5 and 1 to 2.5 parts with water. The hydrated products were added to triangle beef (chuck, brisket, plate) at levels of 20 and 30% by weight. All patties were produced commercially and fat content was 20%. The beef was ground through a 2.54 cm breaker plate, mixed with the hydrated soy product, ground through a 3.2 mm plate, formed into 85-g patties, which were boxed, frozen at −23 C and stored 6 months at −18 C prior to

[1] Mr. E. James Koch provided guidance and assistance with the statistical analysis of the data. The Esskay Meat Packing Company provided facilities; Archer Daniels Midland Company, Cargill Inc., Pfizer Inc., Swift and Company and Central Soya, Inc. provided soy protein samples and technical assistance in patty fabrication. This study was funded in part by the U.S. Army Natick Research and Development Command.

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TABLE 1. PALATABILITY OF BEEF-SOY PATTIES EVALUATED BY A STANDARD PANEL[a]

Product	Tenderness	Flavor	Appearance	Aroma	Juiciness	Overall acceptability
20% level						
TSP[b]						
A	5.6^{abc}	5.6^{ab}	5.9^{a}	5.7^{a}	5.6^{a}	5.4^{abc}
B	5.8^{abc}	5.9^{a}	6.1^{a}	6.1^{a}	5.4^{ab}	5.7^{a}
C	5.7^{abc}	5.3^{abc}	5.5^{ab}	5.7^{a}	5.7^{a}	5.0^{abc}
D	5.6^{abc}	5.6^{ab}	6.0^{a}	5.6^{a}	5.1^{abc}	4.9^{abc}
SC[b]						
E	4.7^{de}	4.2^{de}	4.8^{bcd}	4.7^{bc}	4.6^{cd}	3.9^{d}
F	4.1^{e}	4.1^{de}	5.3^{abc}	4.9^{bc}	3.8^{e}	3.9^{d}
30% level						
TSP						
A	6.3^{ab}	4.8^{bcd}	5.6^{a}	5.5^{ab}	5.6^{a}	4.7^{bc}
B	6.4^{a}	4.5^{cde}	5.8^{a}	5.4^{ab}	5.3^{abc}	4.7^{bc}
C	6.1^{abc}	4.9^{bcd}	5.8^{a}	5.8^{a}	5.7^{a}	4.8^{bc}
D	5.4^{cd}	4.6^{cd}	4.7^{cd}	5.4^{ab}	4.9^{bc}	4.7^{bc}
SC						
E	5.8^{abc}	3.7^{e}	4.5^{d}	4.4^{c}	4.8^{bc}	3.5^{d}
F	4.7^{de}	3.6^{e}	4.4^{d}	4.4^{c}	4.0^{de}	3.4^{d}
All-beef	4.6^{de}	6.0^{a}	5.9^{a}	6.0^{a}	4.9^{bc}	5.5^{ab}

[a]Values within a column followed by the same letter were not different ($P<.05$) according to analysis of variance and Duncan's Multiple Range Test. Each value is based on 32 evaluations. Scores were based on a 9-point scale, 1 = poorest, 9 = best.

[b]TSP – Textured soy protein; SC – Soy concentrate.

TABLE 2. PALATABILITY OF BEEF-SOY PATTIES EVALUATED BY A HOME PANEL OF 52 FAMILIES, EACH EARNING OVER $10,000[a]

Product	Tenderness	Flavor	Appearance	Aroma	Juiciness	Overall acceptability
20% level						
TSP[b]						
A	5.8[ab]	6.2[a]	6.1[a]	6.0[a]	5.2[ab]	5.6[a]
B	6.0[ab]	5.8[a]	6.2[a]	6.2[a]	5.4[a]	6.0[a]
C	5.9[ab]	5.9[a]	6.0[a]	6.1[a]	5.5[a]	5.4[a]
D	5.6[abc]	5.9[a]	6.2[a]	5.9[a]	5.3[ab]	5.4[a]
SC[b]						
E	5.1[bc]	5.9[a]	6.2[a]	6.0[a]	4.7[abc]	5.6[a]
F	5.1[bc]	5.6[a]	5.7[a]	5.6[a]	4.3[bc]	4.9[a]
30% level						
TSP						
A	6.3[a]	5.5[a]	6.0[a]	5.7[a]	5.3[ab]	5.4[a]
B	5.8[ab]	5.9[a]	6.1[a]	5.9[a]	5.2[ab]	5.2[a]
C	5.9[ab]	6.1[a]	6.3[a]	5.9[a]	5.5[a]	5.4[a]
D	5.7[ab]	5.4[a]	5.4[a]	5.6[a]	4.9[abc]	5.4[a]
SC						
E	6.2[a]	6.0[a]	5.9[a]	6.1[a]	5.5[a]	5.1[a]
F	5.0[bc]	5.4[a]	5.7[a]	5.4[a]	4.1[c]	5.0[a]
All-beef	4.7[c]	6.0[a]	6.1[a]	5.8[a]	4.7[abc]	5.9[a]

[a]Values within a column followed by the same letter were not different ($P<.05$) according to analysis of variance and Duncan's Multiple Range Test (1955). Each value is based on the evaluation of 16 families. Scores were based on a 9-point scale, 1 = poorest, 9 = best.

[b]TSP – Textured soy protein; SC – Soy concentrate.

TABLE 3. MEAN SCORES FROM THREE PANELS FOR PALATABILITY OF ALL PATTIES[a]

Panel	Product	Tenderness	Flavor	Appearance	Aroma	Juiciness	Overall acceptability
Standard	20% level – TSP[b]	5.5^{abcd}	5.3^{bcd}	5.8^{bcd}	5.7^{abc}	5.2^{abc}	5.0^{cde}
> \$10,000		5.8^{abcd}	5.9^{abc}	6.1^{abcd}	6.1^{ab}	5.4^{abc}	5.6^{abcd}
< \$10,000		6.2^{ab}	6.5^{ab}	6.6^{ab}	6.7^{a}	5.9^{ab}	6.2^{abc}
Standard	20% level – SC[b]	4.6^{de}	4.1^{de}	5.2^{de}	5.0^{cd}	4.4^{c}	4.0^{ef}
> \$10,000		5.1^{abcde}	5.7^{abc}	6.0^{abcd}	5.8^{abc}	4.5^{c}	5.3^{abcde}
< \$10,000		6.5^{a}	6.4^{ab}	6.3^{abc}	6.5^{ab}	6.3^{a}	6.6^{ab}
Standard	30% level – TSP	6.1^{abc}	4.8^{cde}	5.7^{bcd}	5.5^{bc}	5.4^{abc}	4.6^{def}
> \$10,000		5.9^{abcd}	5.7^{abc}	6.0^{abcd}	5.8^{abc}	5.2^{abc}	5.4^{abcde}
< \$10,000		6.3^{ab}	6.1^{abc}	6.3^{abc}	6.3^{ab}	5.8^{ab}	6.1^{abcd}
Standard	30% level – SC	5.0^{bcde}	3.6^{e}	4.5^{e}	4.4^{d}	4.2^{c}	3.5^{f}
> \$10,000		5.6^{abcd}	5.7^{abc}	5.8^{bcd}	5.8^{abc}	4.8^{bc}	5.1^{bcde}
< \$10,000		6.4^{ab}	6.1^{abc}	6.5^{ab}	6.5^{ab}	5.9^{ab}	6.7^{a}
Standard	All-beef	4.0^{e}	5.6^{abc}	5.8^{bcd}	5.7^{abc}	4.7^{bc}	5.1^{bcde}
> \$10,000		4.7^{cde}	6.0^{abc}	6.1^{abcd}	5.8^{abc}	4.7^{bc}	5.9^{abcd}
< \$10,000		6.4^{ab}	6.8^{a}	7.0^{a}	6.7^{a}	5.9^{ab}	6.7^{a}
Standard	All treatments combined	5.0^{b}	4.7^{b}	5.4^{c}	5.3^{c}	4.8^{b}	4.4^{c}
> \$10,000		5.4^{b}	5.8^{a}	6.0^{b}	5.9^{b}	4.9^{b}	5.5^{b}
< \$10,000		6.4^{a}	6.4^{a}	6.5^{a}	6.5^{a}	6.0^{a}	6.5^{a}

[a]Values within a column of a block followed by the same letter were not different ($P<.05$) according to analysis of variance and Duncan's Multiple Range Test. The standard panel consisted of 52 members; the other panels consisted of 52 families. Scores were based on a 9-point scale, 1 = poorest, 9 = best.

[b]TSP – Textured soy protein; SC – Soy concentrate.

evaluation.

Three consumer panels evaluated the patties. The experimental design was basically a balanced, incomplete block design for 13 treatments with four treatments in an incomplete block and four replications of the treatments in the design. The basic design was used eight times in the standard panel and four times in the family panel. The standard panel consisted of 52 members of ages 18 to 60 years; 13 females and 39 males. They each evaluated four quartered patties without condiments on each of two occasions. Patties provided were cooked on a grill at 177 C for 3 min on each side. The second and third panels consisted of 52 families each with average annual incomes greater or less than $10,000, respectively. The first 52 families in each income level to volunteer were accepted. Families were asked to rate a different patty type each week for 4 weeks. Thus each type of the 13 patties was evaluated by four families each week; by 16 families in 4 weeks. Families were instructed to prepare the patties in any manner desired. Patties and scoring sheets were provided for every member of the family, but only data from members older than 9 were used. Age and sex of all panelists were recorded. Panelists' scores were based on a 9-point scale, 1 for the poorest and 9 for the best. Descriptive terms for scoring codes for tenderness were: 1 – extremely tough; 2 – Very tough; 3 – Moderately tough; 4 – Slightly tough; 5 – Slightly tender; 6 – Moderately tender, 7 – Tender; 8 – Very tender; 9 – Extremely tender. Overall acceptability was rated on a 9-point score wherein a rating of 1 was described by "I would eat this if forced to"; 3 by "I would hardly ever eat this"; 6 by "I like this and would eat it now and then"; and 9 by "I would eat this every opportunity I had."

RESULTS AND DISCUSSION

The standard panel discerned some significant differences among patties for each palatability trait evaluated (table 1). The all-beef patties were usually rates "slightly tough" and were less tender ($P<.05$) than patties containing TSP. Tenderness was about equal for patties containing SC and for all-beef patties. Flavor was rated as slightly desirable for all-beef patties and equal to patties containing 20% TSP and higher than any other patties ($P<.05$). In flavor, patties containing 30% SC were rated in

TABLE 4. EFFECT OF AGE AND SEX OF PANELISTS ON MEAN SCORES FOR PALATABILITY OF ALL PATTIES[a]

Age group	(N)	Tenderness	Flavor	Appearance	Aroma	Juiciness	Overall acceptability
9 – 19	(385)	5.2 ± .02[b]	5.8 ± .02	5.9 ± .02	5.4 ± .02	6.3 ± .02	5.4 ± .03
20 – 29	(87)	5.4 ± .09	5.5 ± .09	5.8 ± .08	5.2 ± .07	4.8 ± .08	5.2 ± .08
30 – 49	(282)	5.8 ± .03	5.8 ± .03	6.0 ± .03	6.0 ± .03	5.0 ± .03	5.5 ± .03
50+	(109)	6.0 ± .07	5.6 ± .07	6.2 ± .06	6.0 ± .05	5.0 ± .08	5.2 ± .08
Total							
Male	(421)	5.4 ± .03	5.7 ± .03	6.0 ± .03	5.6 ± .02	5.3 ± .03	5.4 ± .03
Female	(442)	5.8 ± .03	5.8 ± .03	6.0 ± .02	5.8 ± .02	5.3 ± .03	5.2 ± .03

[a]Based on data from a home panel of 52 families, each earning more than $10,000 annually. Scores were based on a 9-point scale, 1 = poorest, 9 = best.

[b]SE = Standard error of the mean.

the slightly to moderately undesirable range. In appearance, the 30% SC patties were rated slightly undesirable and lower ($P<.05$) than any others except product D of 30% TSP. The aroma of patties with 30% SC was rated slightly undesirable and lower ($P<.05$) than either the all-beef or patties containing TSP. All-beef patties were rated slightly juicy and lower than some of the patties with TSP, but higher ($P<.05$) than the SC product F, which rated slightly dry. In overall acceptability, all-beef patties and some of the patties containing TSP, which scored about 5.5, were described by the phrase "I would eat this now and then." The use of SC at either level reduced the overall acceptability ($P<.05$) to a score a little lower than that described by "I don't like this but would eat it on occasion."

Contrary to the ratings of the standard panel, the panel of families earning over $10,000 a year could not discern any differences among the patties in flavor, appearance, aroma and overall acceptability (table 2). They agreed with the standard panel in rating the all-beef patties less tender than most of the patties containing TSP at either concentration. The family panel did not detect a significant difference in juiciness between all-beef patties and the others, but classified patties with SC product F as less juicy ($P<.05$) than some of the patties containing TSP.

The third panel (families earning less than $10,000) did not detect any significant differences among the products and scores most palatability traits with a mean about 6. Juiciness which was scored the lowest had a mean score of 5.9. Responses to questions indicated that families in both panels prepared patties by similar methods; possibly families in the third panel had been conditioned to accept extended ground beef.

Mean scores for the three panels are compared in table 3. Except for three instances, the standard panel rated palatability traits lower than either of the other two panels. In every instance, the family panel earning less than $10,000 rated the palatability traits higher ($P<.05$) than the other two panels. These data indicate that the standard panel effectively discerned differences in the palatability of the beef patties and the family consumer panels effectively determined the importance of those differences to the public.

Age of the panelists apparently affected tenderness, juiciness, and aroma scores (table 4). Panelists over 50 scored tenderness more leniently than children of 9 to 19 years. Conversely, children were concerned less with juiciness than were people over 30. People over 30 tended to be less critical of aroma than the younger groups; flavor, appearance and overall acceptability were rated about the same by panelists regardless of age. We thought that panelists over 40 might have found difficulty in discerning flavor, due to loss of taste acuity, but age was not a factor in flavor discrimination.

Contrary to the report by Cross *et al.* (1975), sex did not influence palatability scores of the families earning more than $10,000. The difference was attributed to the types of panels involved. Possibly when patties were cooked by the families' preferred methods, some of the discrete differences among samples and panelists disappeared. Furthermore, types of samples were not compared simultaneously in the home panels because each member of the family panels gave a general opinion about one product each week.

Although type, brand and concentration affected acceptability of soy protein in beef patties, age and sex of the consumer were not major factors in overall acceptability; and probably would not influence the sale of beef patties containing soy protein. The product was most readily accepted by the panel of families who earned less than $10,000 per year, and these are the people who might best benefit from protein extenders.

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STABILITY OF FROZEN GROUND BEEF CONTAINING MECHANICALLY DEBONED BEEF

ABSTRACT

round beef formulations containing three levels of mechanically deboned beef (MDB, 0, 10, and 20%) were stored at −12, −18 and −23°C. nitially and at 2-wk intervals for 24 wk, one chub pack from each ormulation and each storage temperature was removed for chemical nd sensory analysis. Formulation (level of MDB) and storage time had gnificant effects on all palatability traits. Frozen storage temperature ad no significant effect on any of the palatability traits. Interactions etween temperature and time; formulation and time; and formulation nd temperature were nonsignificant There was no evidence that the ormulations containing MDB affected the storage properties of ground eef any more so than ground beef containing 0% MDB.

INTRODUCTION

EARLY ONE BILLION additional pounds of meat per year ould be added to the nation's food supply through a process alled "mechanically deboning" (Fried, 1976). This protein is asted as a human food source. On September 10, 1976, a .S. District court judge halted the use of mechanically deboned meat for human consumption. This injunction stopped SDA from enforcing interim regulations permitting the use f mechanically deboned meat. The injunction did not affect e USDA proposal for the use of mechanically deboned meat JSDA, 1976) but aroused public interest in the safety of this ew product. In addition to the interest in the safety of MDM, onsiderable concern has been expressed by industry and conumers about the palatability, nutritional quality and storage ability of MDM.

Field et al. (1974); Cross et al (1976); and Meiburg et al. 976) reported that products of acceptable palatability and utritional content could be produced from mechanically deoned meat. However, Goldstrand (1975); Lee et al. (1975); leiberg et al. (1976); and Mello et al. (1976) indicated that ome types of mechanically deboned meat could develop oxiative rancidity during storage. Little or no research data are vailable to indicate the storage stability of ground beef conaining MDB; therefore, the objectives of this study were to valuate the effects of storage time, storage temperature and vel of mechanically deboned beef (MDB) on the rate of evelopment of oxidative rancidity and on the palatability of ozen ground beef.

EXPERIMENTAL

eat preparation

Ground beef formulations containing three levels of mechanically eboned beef (0, 10 and 20%) were from the same batches prepared for e palatability study reported by Cross et al. (1977). Raw meat aterials were from USDA Utility triangles (chuck, foreshank, brisket nd plate) and USDA Choice plates that were fabricated under the chedule AA USDA Regulations (1973). Coarse ground samples were andomly selected throughout the daily production (65,000 kg) until eight of a sufficient quantity for formulating the treatments was obined.

All hand boned meat was ground through a 1.90 cm plate with a eiler grinder. Mechanically deboned beef (MDB) was obtained from ecks, backs, ribs and pelvic girdle of USDA Utility carcasses that had een manually boned. These bones were passed through a Weiler bone cutter into a Model AU 4171 Beehive Boning Machine equipped with a cylinder having 0.46 mm diameter holes. Deboned meat was boxed, quick frozen and stored at −34°C for subsequent analysis and product formulation. Prior to formulation, the MDB was ground through a 1.90 cm plate with a Weiler grinder and stored at −20°C. Coarse ground portions of beef and MDB were mixed for 3–4 min in a Chemetron mixer. During mixing, CO_2 snow was injected twice in order to maintain an internal temperature of 7°C or less. Following mixing, three samples were randomly obtained for fat analysis using the Hobart fat testing apparatus. Additional fat or lean was added from USDA Choice plates to adjust the fat content to approximately 23%. After mixing, the individual batches were ground through a 0.32 cm plate using a Weiler grinder. During processing the product internal temperature did not exceed 7°C. The product from each treatment was stuffed into 1 kg Cryovac Keeper Casings via a VeMag Pump (Model 43). The chub packs were boxed separately and placed in a −45°C blast freezer for 48 hr and subsequently sorted at −30°C until shipment. The frozen product was shipped to Beltsville, MD, via truck at −20°C.

Storage treatments

Ground beef chub packs from each treatment (0, 10 and 20%) were stored at −12, −18 and −23°C. Initially and at 2-wk intervals, one chub pack from each formulation and each storage temperature was removed for subsequent thiobarbituric acid (TBA) and sensory analysis. Each chub pack was thawed at 2–3°C for 24 hr and formed into 113g patties 0.95 cm in thickness with a Hollymatic Model 200 patty machine. Patties were refrozen at −30°C for 6 hr and were cooked from the frozen state.

Rancidity

For TBA determination, two patties from each treatment were randomly selected, frozen in liquid nitrogen and powdered in a high speed blender. Rancidity, as TBA values, was determined by the procedures of Tarladgis et al. (1960).

Cooking

Frozen patties were broiled 14 min (7 min on each side) on a Farberware (model 450) electric grill to a "medium" degree of doneness (photographic color scale).

Sensory panel evaluations

Cooked patties were evaluated by a trained panel. Procedures for selection and training of the panel are described by Cross et al. (1978). The seven panelists rated patties from each formulation for differences in tenderness and juiciness on a 8-point rating scale (8 = extremely tender or juicy and 1 = extremely tough or dry). The amount of connective tissue residue remaining at the end of mastication was rated on an 8-point scale (8 = none and 1 = abundant amount). The panel was trained to evaluate differences in tenderness, juiciness and amount of connective tissue. The panel also subjectively evaluated the samples for desirability of appearance, aroma, flavor and for overall desirability (8 = extremely desirable and 1 = extremely undesirable). The entire study consisted of twelve 3-day taste sessions over a period of 6 months (36 sessions total). Four samples were presented to the panel at each session.

Statistical analysis

Data for each sensory variable was treated by analysis of variance (ANOVA) to test the effects of MDB level, storage temperature, storage time and some of the important interactions. With the taste panel responses as a vector, a multivariate analysis of variance was also preformed (Press, 1971).

RESULTS & DISCUSSION

ANOVA and subsequent F tests for level of MDB, storage temperature and storage time are summarized in Table 1. All

Table 1—Analysis of variance for taste panel palatability traits

Source	Significance of F-ratios						
	Tenderness	Juiciness	Flavor	Connective tissue	Appearance	Aroma	Desirability
MDB level	**	**	**	**	*	*	*
Storage temperature	NS[a]	NS	NS	NS	NS	NS	NS
Storage time	**	**	**	**	**	**	**
MDB/time	NS	NS	NS	NS	NS	NS	NS
MDB/temperature	NS	NS	NS	NS	NS	NS	NS
Temperature/time	NS	NS	NS	NS	NS	*	NS

a NS = nonsignificant
* P < 0.05
** P < 0.01

latability traits were significantly (P < 0.01 or P < 0.05) ected by MDB level and storage time but not by frozen rage temperature. Among main effects only the interaction temperature by time for aroma was significant.

Results of the multivariate analysis corresponding to the NOVA in Table 1 appear in Table 2. The multivariate alysis confirmed that MDB level and storage time were the ost important main effects. The fact that there was no sig- icant interaction between MDB level and time in the multi- iate analysis of variance indicated that the beef patties teriorated with time at the same rate for each treatment DB level).

Table 2—Multivariate analysis of varience (taste panel traits combined)

Source	Significance of F-ratios
MDB level	**
Storage temperature	NS[a]
Storage time	**
MDB/time	NS
MDB/temperature	NS
Temperature/time	NS

a NS = nonsignificant
** Significant at the P < 0.01 level of probability

Therefore, for each palatability trait, only one equation, containing an intercept correction for each treatment, is needed to relate time to quality. The equation in its three forms, one for each MDB level, and the associated R^2's are given in Figures 1–7. For each palatability trait, three functions were plotted—one for each MDB level. Because there was no MDB level by time interaction for each palatability trait, the three lines have the same slope. The separations among the lines reflect the mean differences among MDB levels.

Generally, the panel ratings for tenderness increased with the level of MDB (Fig. 1). Figure 1 confirms the results of Cross et al. (1977) that ratings for tenderness increased with level of MDB and that ground beef containing MDB deteriorated at the same rate at ground beef containing no MDB. It is commonly accepted that data from trained panels do not always accurately predict levels of consumer acceptance or preference. Many researchers who have compared data between trained and consumer panels found that meat that was rated "slightly tough, dry," etc., by trained panelists was usually rated "slightly unacceptable" by consumers. On a 8-point scale that rating would correspond to less than 5. When, on the basis of that comparison, we assigned 5.0 as the minimum acceptable panel rating, samples with 0% MDB were "unacceptable" at about 14 wk whereas samples with 10% and 20% MDB were still acceptable at 24 wk.

The report of Cross et al. (1977) was confirmed in that juiciness ratings were not affected significantly by level of MDB (Fig. 2). Juiciness ratings decreased with time but were still above the "unacceptable" (less than 5.0) cutoff at 24 wk.

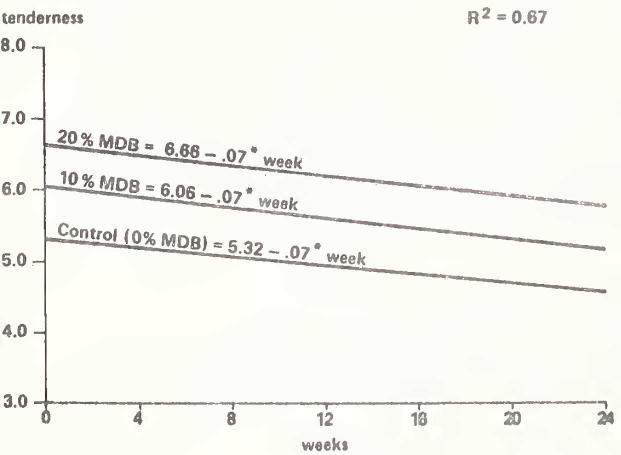


Fig. 1—A linear function in terms of time for MDB level and tenderness (Significant at P < 0.05).

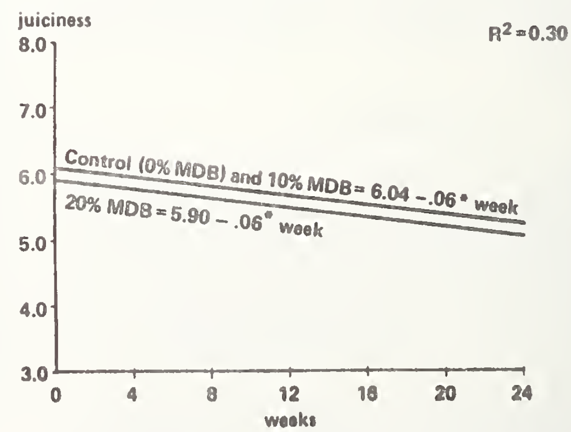
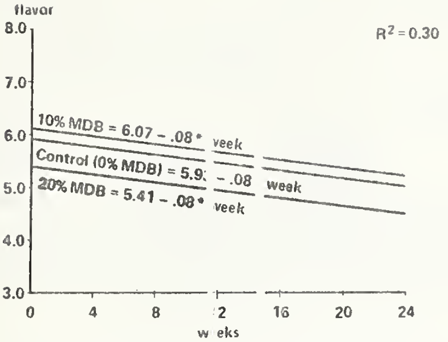


Fig. 2—A linear function in terms of time for MDB level and juiciness (Significant at P < 0.05).



g. 3–A linear function in terms of ime for MDB level and flavor ignificant at P < 0.05).

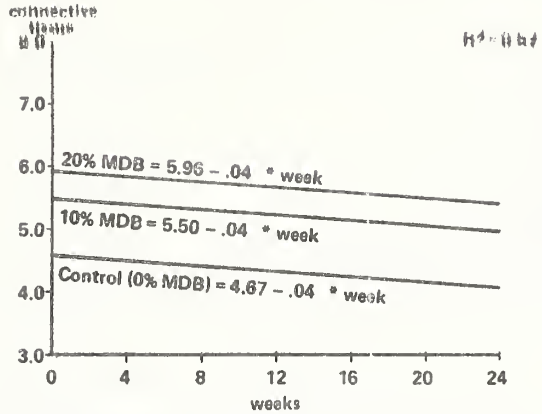


Fig. 4–A linear function in terms of time for MDB level and connective tissue (Significant at P < 0.05)

Flavor ratings were lowest in he ground beef containing % MDB, whereas, rate of decli e did not differ among the ee levels. Ground beef co tair ing 20% MDB reached the rderline in flavor acceptability after about 10 wk of storage g. 3).

As reported by Cross et al. (1977) detectable connective sue decreased with increased le els of MDB. The 0% MDB und beef initially was "unacceptable" in amount of conctive tissue (Fig. 4). Cross et al. (1976) reported that ground ef from U.S. Utility grade beef is unacceptably high in amount connective tissue. Ground bee with 10% and 20% MDB s "acceptable" throughout the 24 wk of storage.

Level of MDB had no significant effects on appearance or ma (Fig. 5 and 6). Mean panel ratings decreased with time both traits but were abou 5.0 after 24 wk. Addition of B did not affect the rate of dec ine for overall desirability h storage time (Fig. 7). Ground beef approached the 5.0 off in about 13 wk for 20% MDB, in 16 wk for 0% MDB in about 24 wk for 10% MDB.

Results of ANOVA for the effects of MDB level, storage perature, and storage time on TBA values appear in Table The main effects for MDB level and storage time were sigcant (P < 0.01), whereas the main effect for storage perature was not. Interaction or MDB level by storage perature was significant (P < 0.01). The significant effect storage time on TBA was not described by a linear or

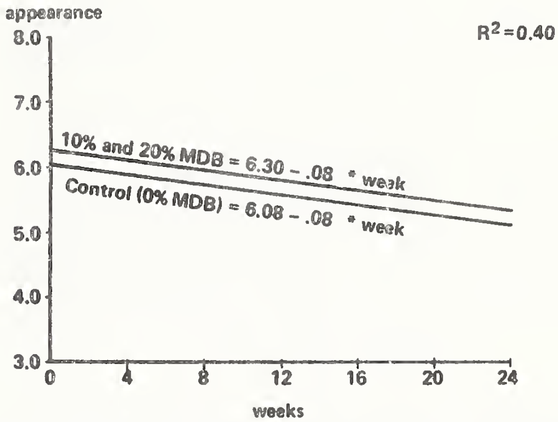
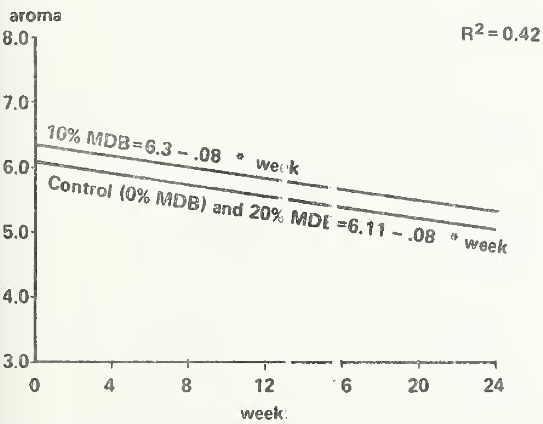


Fig. 5–A linear function in terms of time for MDB level and appearance (Significant at P < 0.05).

quadratic function and therefore, was treated as a block effect caused by some controlled factor. Because there was a significant MDB level by temperature interaction we used Scheffe's method for multiple comparisons for differences among the three levels for each storage temperature.



ig. 6–A linear function in terms of time for MDB level and aroma Significant at P < 0.05).

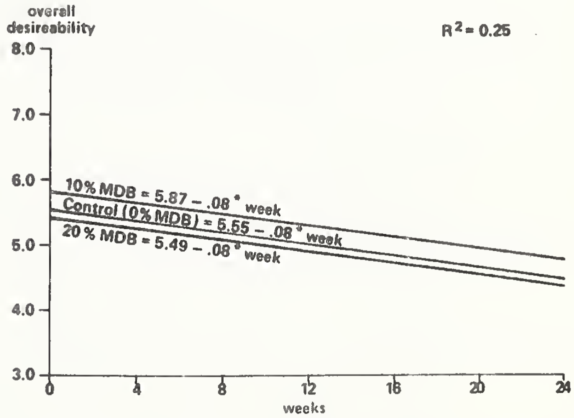


Fig. 7–A linear function in terms of time for MDB level and overall desirability (Significant at P < 0.05).

Table 3—Analysis of variance for TBA values

Source	Significance of F-ratio
MDB level	**
Storage temperature	NS[a]
Storage time	**
MDB/time	NS
MDB/temperature	**
Temperature/time	NS

[a] NS = nonsignificant
** Significant at the P < 0.01 level of probability.

Table 4—Mean TBA values at three storage temperature and three levels of MDB[a]

Level of MDB (%)	Storage temperature °C −12	−18	−23
0	$0.436^{c,1}$	$0.474^{c,1}$	$0.606^{b,2}$
10	$0.615^{b,1}$	$0.686^{b,2}$	$0.538^{bc,1}$
20	$0.397^{c,1}$	$0.394^{c,1}$	$0.444^{c,1}$

[a] Means in the same column with no superscripts in common are significantly different (P < 0.10). Numbers in the same row that have different superscripts are significantly different (P < 0.10)

Mean TBA values at three storage temperatures and three levels of MDB appear in Table 4. Storage temperature effects are compared within each MDB level by the numberical superscripts in the rows; the MDB level effects are compared by the letter superscripts within the columns. For 0% MDB, TBA values increased as storage temperature decreased, but the difference was significant only at −23°C. For 10% MDB, TBA values were significantly higher at −18°C than at −12 or −23°C. For 20% MDB, TBA values were not significantly affected by storage temperature. These differences, although significant are likely of no practical importance.

At −12 and −18°C storage temperature, TBA values were significantly higher for 10% MDB, while 0% MDB at −23°C had the highest TBA values. It is questionable whether the magnitude of the differences in TBA values is great enough to be of practical importance. Usually, depending on the product, TBA values must exceed 1.0 before a trained panel could detect differences in flavor.

CONCLUSIONS

FROM OUR DATA pertaining to the storage properties of ground beef containing MDB we conclude:

1. Temperature of frozen storage had no significant effects on palatability traits.

2. Rates of deterioration for palatability traits were not affected by level of MDB.

3. Ground beef containing 20% MDB approached the flavor score we defined as unacceptable after 10 wk at sub-freezing temperatures; while ground beef with 10% or 0% MDB still had acceptable flavor scores after 24 wk.

4. Although some significant differences were shown among treatments, TBA values for all formulations were below the value corresponding to a level of oxidative rancidity that would be consistently detected by trained or consumer panelists.

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Dye Reduction Method for Estimating Bacterial Counts in Ground Beef

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A dye reduction method was developed for estimating total aerobic and/or psychrotrophic bacterial counts in ground beef. The method is based on color changes in indicator disks placed on the meat surface.

The use of chemical indicators as agents for the determination of sanitary quality of milk is well known (3, 4, 8). Various redox indicators have also been used as rapid tests for assessing the bacteriological quality and/or predicting the shelf life of other foods, including maple sap (5, 6), red meats (1, 2, 9–11), poultry (12, 14), and eggs, seafood, and vegetables (7, 13).

The purpose of this study was to develop a simple chemical reduction method for estimating the level of microbial contamination in ground beef. Such a method would prove advantageous if a meat wholesaler, retailer, or consumer could estimate the bacterial content of a package of ground beef by visual observation of color changes in an indicator disk placed on the meat surface at the time the meat was packaged.

We used three redox indicators, methylene blue (MB; Difco), 2,3,5,-triphenyltetrazolium chloride (TTC; Difco), and resazurin (RZ; Manufacturing Chemists, Norwood, Ohio). MB changes from blue to colorless upon reduction; TTC changes from colorless to red (triphenylformazan); and resazurin changes from blue to pink (resofurin) to colorless (hydroresofurin). Ten concentrations (0.0025, 0.005, 0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.64, and 1.28%) of each indicator were tested. A preliminary study with plates seeded with a mixed culture and five bacterial isolates from ground beef showed that none of the above concentrations of any of the indicators gave measurable zones of inhibition of bacterial growth around the disks on the seeded plates.

The indicators were dissolved in distilled water and 0.1 ml of solution was placed on each Whatman no. 2 filter paper disk (1 cm in diameter). The disks were dried at room temperature overnight in the dark after which half of the disks were covered on one side with one drop (Pasteur pipette) of sterile 2% agar. Initial relative intensity readings of all the disks (with and without agar) were then made on an Aminco Microphotometer (Travenol Laboratories, Inc., Silver Spring, Md.) with an Uniscan attachment having a 0.5-mm slit and the standard ultraviolet light source emitting maximum energy at 360 nm. The agar layers were added and initial relative intensity readings were recorded immediately before the disks were placed on the ground beef patties.

A total of 112 fresh 3-ounce (ca. 85 g) ground beef patties representing two different batches from each of two processors were used in this study. Two control patties from each of the four batches were evaluated for initial total aerobic and psychrotrophic bacterial counts the day after the patties were delivered from the processors. On the same day, five disks representing five different concentrations of a given redox indicator were lightly pressed with forceps onto each of 96 patties. The agar surfaces of the disks were placed adjacent to the patties. Metricel membranes (Gelman Instrument Co.; 13 mm in diameter; 0.45-μm pore size) were placed between the ground beef patties and the disks without an agar layer. Thus, eight patties (two from each batch) were tested for each treatment (3 dyes $\times$ 10 concentrations/5 concentrations per patty $\times$ agar surface versus Metricel membrane). The purpose of the agar surfaces and the Metricel membranes was to minimize the absorption of meat juices by the indicator disks.

The patties were placed in individual plastic bags (Baggies sandwich bags) and stored at 5 C. The eight remaining patties served as 5-day and 12-day controls. Half of the patties were evaluated after 5 days of storage and the remaining half after 12 days for total aerobic and psychrotrophic bacterial counts and relative intensity readings of the disks. Serial dilutions of the bacteria from an 11-g core sample (4 cm in diameter) from the center of each patty were made in phosphate-buffered diluent and

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plated on plate count agar (Difco) in cluster dishes. Plates for total aerobic counts were incubated for 48 h at 35 C and plates for psychrotrophic bacterial counts were incubated for 10 days at 5 C.

Initial mean log counts of total aerobic and psychrotrophic bacteria in the ground beef patties were 5.68 and 5.91, respectively. Mean log counts after 5 days of storage were 6.38 (range 4.86 to 7.50) for total aerobes and 7.12 (range 5.86 to 7.88) for psychrotrophs. After 12 days of storage, the mean log counts of total aerobic and psychrotrophic bacteria were 7.86 (range 7.04 to 8.39) and 8.41 (range 7.67 to 8.76), respectively.

Table 1 presents the correlation coefficients for total aerobic bacterial counts and relative intensity readings of the indicator disks. Table 2 presents the same data for psychrotrophs. Indicator disks with Metricel membranes gave better correlations with counts than the disks with agar surfaces. Differences in the thickness of the agar layer and in the amount of indicator absorbed from the disk by the agar caused variability in relative intensity readings among agar indicator disks. Reduction was better correlated to bacterial counts with MB than with TTC or RZ. MB disks (with membranes) at the concentration of 1.28% gave r values of 0.91 for total aerobic bacteria and 0.97 for psychrotrophic bacteria. A major disadvantage inherent in the use of TTC is that the reduced compound (triphenylformazan) is red which makes it difficult to determine whether color changes are due to reduction caused by bacterial metabolites or to the absorption of meat juices by the disk. Psychrotrophic bacterial counts were better correlated than total aerobic counts to reduction of the indicators, a fact which is not surprising since it is primarily the psychro-

TABLE 1. *Correlation between total aerobic bacterial counts ($\log_{10}$) in ground beef patties and relative intensity readings of the redox indicator disks*

Redox indicator concn (%)	Correlation coefficients (r values)					
	Methylene blue		Tetrazolium		Resazurin	
	Agar	Membrane	Agar	Membrane	Agar	Membrane
0.0025	0.51	0.71[a]	−0.61	−0.82[a]	−0.28	−0.49
0.005	0.66	0.46	−0.87[b]	−0.79[a]	−0.38	−0.49
0.01	0.65	0.43	−0.62	−0.77[a]	−0.53	0.06
0.02	0.63	0.62	−0.75[a]	−0.94[b]	0.20	−0.62
0.04	0.68	0.59	−0.61	−0.72[a]	−0.06	−0.54
0.08	0.58	0.80[a]	−0.73[a]	−0.47	0.65	−0.11
0.16	0.54	0.86[b]	−0.65	−0.88[b]	0.32	0.64
0.32	0.58	0.88[b]	−0.51	−0.69	0.64	0.44
0.64	0.55	0.90[b]	−0.53	−0.52	0.73[a]	0.76[a]
1.28	0.56	0.91[b]	−0.34	−0.39	0.55	0.62

[a] $P < 0.05$.
[b] $P < 0.01$.

TABLE 2. *Correlation between psychrotrophic bacterial counts ($\log_{10}$) in ground beef patties and relative intensity readings of the redox indicator disks*

Redox indicator concn (%)	Correlation coefficients (r values)					
	Methylene blue		Tetrazolium		Resazurin	
	Agar	Membrane	Agar	Membrane	Agar	Membrane
0.0025	0.74[a]	0.87[b]	−0.56	−0.65	−0.07	−0.72[a]
0.005	0.83[a]	0.68	−0.86[b]	−0.59	−0.60	−0.65
0.01	0.83[a]	0.72[a]	−0.63	−0.57	−0.40	−0.26
0.02	0.82[a]	0.76[a]	−0.69	−0.87[b]	0.17	−0.77[a]
0.04	0.83[a]	0.77[a]	−0.63	−0.70	−0.11	−0.49
0.08	0.87[b]	0.85[b]	−0.76[a]	−0.34	0.63	0.02
0.16	0.85[b]	0.87[b]	−0.67	−0.75[a]	0.57	0.90[b]
0.32	0.86[b]	0.86[b]	−0.49	−0.71[a]	0.78[a]	0.82[a]
0.64	0.85[b]	0.90[b]	−0.52	−0.38	0.82[a]	0.92[b]
1.28	0.85[b]	0.97[b]	−0.33	−0.45	0.77[a]	0.91[b]

[a] $P < 0.05$.
[b] $P < 0.01$.

TABLE 3. *Equations for predicting bacterial counts ($\log_{10}\hat{y}$) from redox indicator disk relative intensity readings (χ)*[a]

Microorganism	Redox indicator concn	Correlation coefficient	Coefficient of determination	Regression equation	Standard error of estimate
Total aerobes	MB (m)[b], 1.28%	0.91	83.14%	$\log \hat{y} = 0.07687\ \chi + 3.19390$	0.46
	TTC (m), 0.02%	−0.94	87.44%	$\log \hat{y} = -0.09859\ \chi + 13.19014$	0.34
	RZ (m), 0.64%	0.76	57.04%	$\log \hat{y} = 0.27831\ \chi - 6.70572$	0.86
Psychrotrophs	MB (m), 1.28%	0.97	94.46%	$\log \hat{y} = 0.07443\ \chi + 3.96330$	0.24
	TTC (m), 0.02%	−0.87	76.00%	$\log \hat{y} = -0.08726\ \chi + 13.17311$	0.45
	RZ (m), 0.64%	0.92	84.84%	$\log \hat{y} = 0.24805\ \chi - 4.32307$	0.37

[a] Based on eight observations.
[b] m, Metricel membrane.

trophic bacteria which produce metabolites at 5 C.

Table 3 presents the regression equations for predicting total aerobic and/or psychrotrophic bacterial counts in ground beef from relative intensity readings of the reduced indicator disks. The MB method was more acceptable than the TTC and RZ methods; however, equations are presented for the concentration of each indicator which produced the best results. The results of this study show that MB dye reduction can be used to predict bacterial counts in ground beef. Although the ground beef patties used in this study were evaluated after 5 and 12 days of refrigerated storage, the MB disk reduction method could be used to estimate the bacterial quality of ground beef stored for any given period of time. The relative intensity reading on a microphotometer requires only minutes, whereas plating, incubation, and counting procedures require 2 days for total aerobic bacteria and up to 10 days for psychrotrophic bacteria.

Although these data indicate that MB reduction is an effective, rapid method for estimating bacterial counts in ground beef, further evaluation would be required before this procedure could prove useful in a meat packing plant or a supermarket. Standards of MB color, each representing a particular bacterial level, might be developed for visual comparison with the MB indicator disk. Visual comparison would eliminate the requirement for an instrument, but would introduce subjective error. Also, further studies are necessary to determine the effect of meat storage time and temperature on the degree of reduction (color change) and to establish whether there are minimal bacterial levels below which the method loses accuracy.

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Bacteriological Quality and Shelf Life of Ground Beef

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The bacteriological quality of unfrozen raw ground beef was evaluated after 0, 3, 6, 9, 12, 15, and 18 days of storage at 29 ± 1 F (-1.7 ± 0.6 C). At the time of fabrication, all of the ground beef samples contained 10^6 or fewer total aerobic and psychrotrophic bacteria/g; 81% contained 100 or fewer coliforms/g; 94% contained 100 or fewer *Escherichia coli*/g; and all of the samples contained 100 or fewer coagulase-positive *Staphylococcus aureus* and *Clostridium perfringens*/g. Total aerobic and psychrotrophic bacteria increased by 1 log between 3 and 18 days of storage. Coliform and *E. coli* counts decreased during storage, whereas coagulase-positive *S. aureus* and *C. perfringens* counts did not change significantly. These data indicate that meat processors, wholesalers, and retailers could improve the bacteriological quality and prolong the shelf life of ground beef packaged in oxygen-impermeable film if the temperature of the product never exceeded 29 ± 1 F (−1.7 ± 0.6 C).

Ground beef provides a favorable environment for the growth of bacteria. Bacteria normally found on the meat surface are distributed throughout the entire product during the grinding and mixing processes used in fabrication of ground beef. The bacterial population in ground beef depends upon the bacteriological quality of the trimmings and cuts of beef that are ground, sanitation during fabrication, type of packaging, and time and temperature of storage.

During the past few years, there has been an increased interest on the part of governmental agencies toward establishing microbiological criteria or standards for various food products, including ground beef. Some states (e.g., Oregon), cities, and counties have developed standards or guidelines to be enforced at their levels, and federal agencies are also active in developing various criteria (R. W. Johnston, Meat Industry Res. Conf., Univ. of Chicago, Chicago, Ill., 20-21 March 1975). The Center for Disease Control (10) has reported that ground beef is infrequently involved in foodborne outbreaks, even though pathogens such as coagulase-positive staphylococci and *Clostridium perfringens* can be isolated. Goepfert and Kim (3) concluded that even if ground beef is abused or mishandled, the pathogens which are present cannot multiply because they cannot compete with spoilage organisms which are present. However, the Center for Disease Control (11) recently reported on an extensive outbreak of salmonellosis (*Salmonella newport*) from hamburger eaten raw or rare. Proponents of microbiological standards insist that standards would improve the quality of ground beef.

The present study was conducted to determine (i) the bacteriological quality of unfrozen ground beef produced by a federally inspected processor and (ii) the bacteriological quality and shelf life of the product after storage at 29 ± 1 F (−1.7 ± 0.6 C) for 3, 6, 9, 12, 15, and 18 days.

MATERIALS AND METHODS

The ground beef used in this study was fabricated commercially under federal inspection and supplied, unfrozen, in 3-pound (1,361-g) chub packs. The product was fabricated from chilled cow beef (rounds and chucks), chilled beef flanks, line trimmings, and frozen flaked cow beef. The meats were passed through a coarse grinder (6.35-mm plate), then mixed in proportions not to exceed 25% fat content. The product was then passed through a fine grinder (3.17-mm plate) and finally through a packaging machine which stuffed ground beef into oxygen-impermeable casings to make the 3-pound chub packs. The final product is usually held overnight at −1.1 C and shipped to retail stores the following day. However, the chub packs used in this study were transported (20 min) the same day they were fabricated to the Beltsville Agricultural Research Center, where they were stored at −1.7 ± 0.6 C until they were analyzed.

Ground beef samples were taken from two different batches (early morning and midmorning) on each of 4 days (1 day every 2 weeks) at the meat processing plant. Two 11-g samples of ground beef from each of the eight batches were taken from the

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INFLUENCE OF ADDED SOY PROTEIN ON ELECTROPHORETIC PATTERNS OF THE WATER-SOLUBLE PROTEINS OF COOKED BEEF PATTIES

ABSTI AC

atties containing all beef, 20% or 30% of either textured soy protein TSP) or concentrate (SC) were cool ed fo r different time–temperature ombinations that, for the all-beef patties, produced rare (58°C), medi- n rare (62°C), medium well (66°C) and well (68°C) done meat. Sodi- m dodecyl sulfate-acrylamide gel electrophoresis of the water extract f the cooked patties yielded eight bands of different intensities. The tensities of seven bands decreased significantly ($P < 0.001$) with in- easing degree of meat doneness. Seven of the eight band intensities ecreased significantly ($P < 0.001$) with the addition of soy protein. he intensity of the eight bands whi h were 20.4, 12.9, 10.9, 12.6, 8.6, 4.6, 135.4 and 60.0 for the cooked, all-beef patties were reduced to 9, 5.2, 0.6, 1.2, 4.4, 2.7, 24.4 and 2. respectively, for the patties ntaining 30% added SC. The denaturation of the soluble proteins was eater in patties containing SC than TSP, as indicated by reduction of tensity in seven of the eight bands. The change in cooking character- ics was probably due to co-denaturation of the soluble meat protein ith the soy protein.

INTRODUCTION

HEN THE COST of meat increased, supplementation of eat products with vegetable proteins, such as textured soy otein or soy concentrate, became an economic reality. The ldition of soy protein to meat can be detected, in both raw id cooked products, by electrophoretic techniques (Lee et al. 975, 1976).

The influence of cooking beef on the denaturation of pro- ins and on the resultant electrophoretic patterns has been udied. Fogg and Harrison (1975), who recognized the impor- nce of internal endpoint temperature on palatability and ceptance of meat, studied the influence of two endpoints, °C and 45°C in semitendinosus muscle on the electro- oretic patterns of the sarcoplasmic proteins. They con- uded that heating to 25°C decreased the number and inten- y of the slowest migrating protein components of the rcoplasmic fraction, and the effects were more pronounced 45°C. Lee et al. (1974) demonstrated that cooking meat at degree increments from 65°C to 90°C caused a progressive eakening and disappearance of the electrophoretic bands un- , at 90°C, only one, myoglobin, of the six original bands mained. Those authors reported that the disappearance of e bands was so precise in relation to temperature increase, at they recommended electrophoresis for determining the mperature to which meat had been cooked. They indicated at the procedure could be used to ensure that meat had been oked to 69°C as a precaution against foot-and-mouth disease rus that might be found in imported meat.

We have investigated the influence of the addition of soy otein to beef on the denaturation of water-soluble proteins ring cooking, as measured by changes in electrophoretic pat- rns, and the relation of those changes to internal endpoint mperature (apparent degree of doneness).

EXPERIMENTAL

mple preparation

Textured soy protein (TSP) and soy concentrate (SC) were hydrated 1:1.5 and 1:2.5 with water respectively, as recommended by the School Lunch Program (USDA, 1971). The beef, 75/25 (lean to fat) plate, chuck and brisket from U.S. Good carcasses, was ground through a 2.54 cm plate. Hydrated soy proteins were added to the beef to levels of 20 and 30%. The mixtures were ground through a final 0.32 cm plate and automatically formed into 85g, 11 mm thick patties. All-beef patties (control) were prepared in a similar manner, without soy protein. The five types of patties were packaged in corrugated boxes lined with plastic, frozen at −25°C and stored at −17°C until evaluated.

Patties were cooked from the frozen state on a grill to doneness endpoints of rare (58°C–internal temperature of patty), medium rare (62°C), medium well (66°C) or well (68°C). Three time-temperature combinations were used to obtain each degree of doneness, as tabulated below. Patties were visually categorized as to degree of doneness.

Griddle temp (°C)	Doneness: Rare (min)	Med rare (min)	Med well (min)	Well done (min)
121	8	9	10	11
149	5	6	7	8
177	4	5	6	7

Three patties of each of the five types were cooked at each time-temperature, then cooled. Various time-temperature relationships were used for each degree of doneness to introduce variability in cooking methodology which might be encountered under normal circumstances. A 5–10g core sample of the center of each of the 180 cooked patties was homogenized, with an equal weight of water at 16,000 rpm for 2 min, centrifuged for 15 min at 16,000 × G and filtered through Whatman No. 1 paper. The filtrate was used for electrophoretic determination of soluble proteins.

Sodium dodecyl sulfate (SDS) acrylamide gel electrophoresis

The method of Lee et al. (1974) was used for electrophoresis, and times were 3–4 hr. The number, migration distance and density of the stained bands were measured with an Aminco Microphotometer. Relative densities were recorded as area under the peak produced by each band and expressed in tenths of a square centimeter.

Statistical analyses

The data were treated by analysis of variance (Snedecor and Cochran, 1972) and the Multiple Range Test (Duncan, 1955).

RESULTS & DISCUSSION

Denaturation of all-beef patties

Figure 1 shows the SDS-acrylamide electrophoretograms of the water-soluble proteins from uncooked beef, beef-soy patties and soy proteins. Figure 2 shows band intensities of all-beef patties cooked to four internal temperatures, 58°C, 62°C, 66°C and 68°C representing four degrees of doneness, rare, medium rare, medium well and well, respectively. The loss of intensity of the bands is similar but not as marked as that reported by Lee et al. (1974) for beef cooked to endpoints of 65–90°C. The mean electrophoretic band intensities of all-beef patties are reported in a later table (4). The intensity of band 7 (myoglobin), which Lee et al. (1974) reported to be

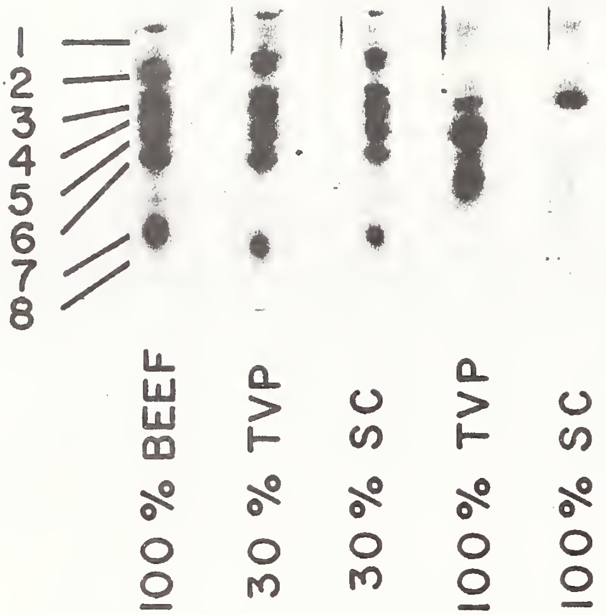

Fig. 1—SDS-acrylamide electrophoretograms of water soluble proteins from uncooked beef, beef-soy patties and soy proteins.

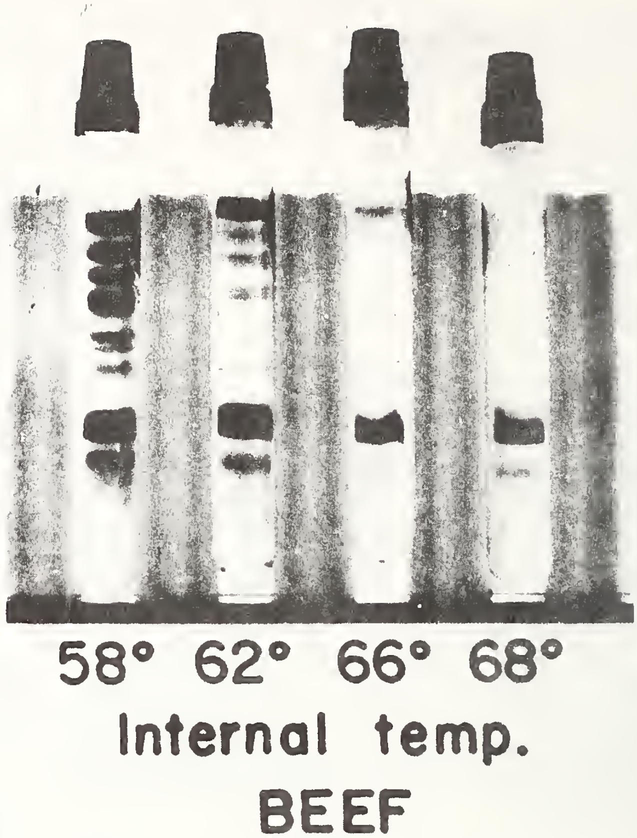

Fig. 2—SDS-acrylamide electrophoretograms of water soluble proteins from cooked beef patties.

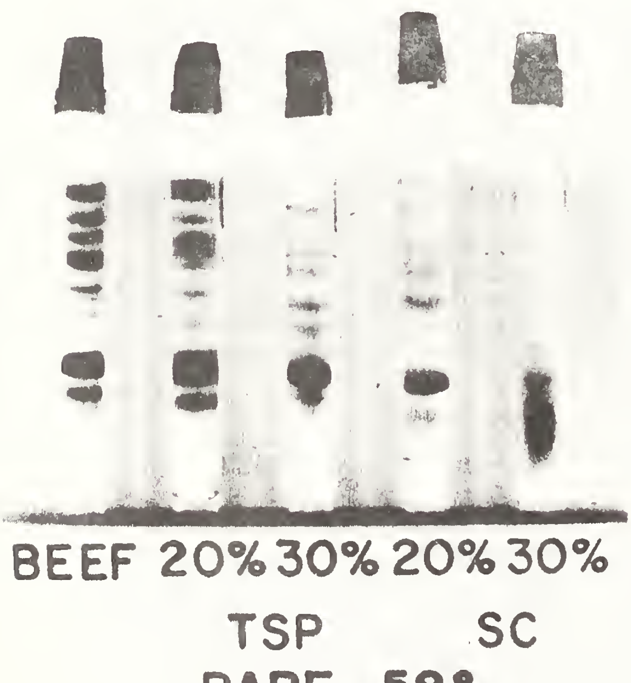

Fig. 3—SDS-acrylamide electrophoretograms of water soluble proteins from "rare" beef patties containing soy protein.

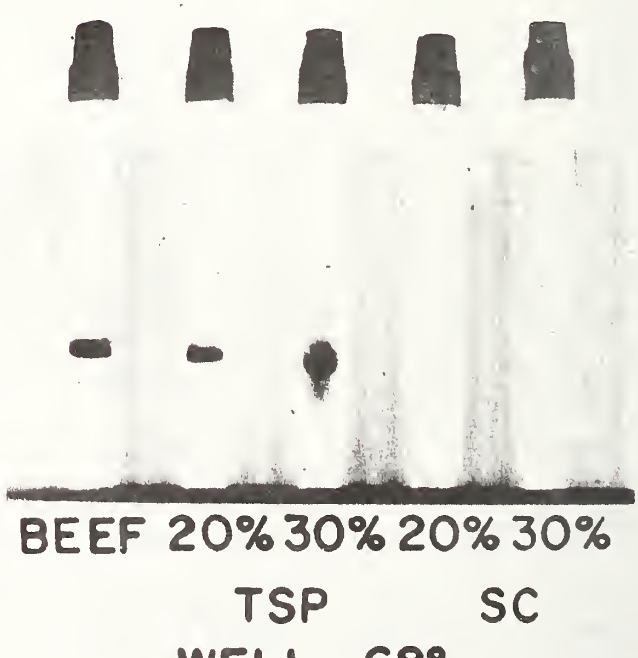

Fig. 4—SDS-acrylamide electrophoretograms of water soluble proteins from "well" beef patties containing soy protein.

the most resistant to heat denaturation, was not significantly different for beef cooked to endpoints of 58–66°C.

Effect of griddle temperature on beef-soy patty band intensities

The electrophoretic patterns of cooked beef patties containing soy protein displayed eight distinct bands. Only band 7 was significantly influenced by griddle temperature (Table 1). The mean intensities of band 7 were 92.6, 75.6 and 70.0 for 60 patties cooked at 121, 149 and 177°C, respectively. Griddle temperatures of 149 and 177°C significantly decreased the intensity of band 7.

Influence of degree of doneness on intensities of protein bands

We evaluated only one brand each of TSP and SC. Processing techniques for TSP and SC vary among companies and might influence electrophoretic bands because high processing temperatures would increase denaturation of protein.

The intensities of all eight bands from patties containing soy protein were influenced significantly ($P < 0.001$, for bands 1–7; $P < 0.05$, for band 8) by degree of doneness to which the patties were cooked (Table 1). Table 2 shows decreases of intensity of 86, 77, 82, 87, 81, 64, 51 and 27% for bands 1 through 8, respectively, as the beef-soy patties were heated from 58°C to 68°C. These data agree with those of Fogg and Harrison (1975) who reported a decrease in number and intensity of the protein components having the largest molecular weight (the components migrating the shortest distance) with increasing temperatures.

Effect of soy additives on band intensity

Kotula and Rough (1975) reported that under similar con-

Table 1—Mean square densities of electrophoretic bands and their significance obtained from analysis of variance

Source	df	Band 1	2	3	4	5	6	7	8
Corrected total	179								
Temp of griddle	2	15.9	9.2	1.1	56.6	89.5	103.6	8337.6**	174.5
Doneness	3	1701.6***	1566.1***	829.9***	1671.7***	1213.9***	300.0***	26492.0***	1018.8*
Temp X doneness	6	36.0	82.7	103.2*	72.3	60.3	70.6	737.3	745.9*
Soy	4	2061.8***	509.1***	635.8***	615.5***	341.2***	835.2***	73703.5***	22151.9***
Temp X soy	8	105.6	84.9	35.2	99.3	15.9	36.5	615.6	354.4
Doneness X soy	12	363.5***	135.2	120.2**	209.8***	80.5	93.9	2075.2	575.5
Temp X doneness X soy	24	91.4	72.7	37.9	80.5	67.2	58.3	3030.9**	858.8
Error	120	80.3	80.3	43.0	59.9	61.6	60.4	1320.4	291.2

* ($P < 0.05$)
** ($P < 0.01$)
*** ($P < 0.001$)

Table 2—Mean electrophoretic band intensity of beef-soy patties as influenced by degree of patty doneness[a]

Doneness	Temp (°C)	Band[b] 1	2	3	4	5	6	7	8
Rare	58	17.1a	16.0a	11.8a	15.2a	15.4a	9.9a	112.9a	24.7a
Medium rare	62	8.0b	4.9b	4.9b	4.2b	7.6b	6.4b	77.0b	15.5b
Medium well	66	6.7b	4.3b	3.6b	3.4b	7.0b	5.8b	72.3b	25.0a
Well	68	2.4c	3.6b	2.1b	1.9b	3.0c	3.7b	55.2c	18.0ab

[a] Means within a column followed by the same letter are not significantly different ($P < 0.05$) (Duncan, 1955). Each value is the mean of 45 determinetionetions.
[b] Relative intensities reported as area under the peak in 0.1 cm^2.

Table 3—Mean electrophoretic band intensity of cooked beef patties as influenced by addition of soy protein[a]

Product	Band[b] 1	2	3	4	5	6	7	8
All-beef	20.4a	12.9a	10.9a	12.6a	8.6ab	14.6a	135.4a	60.0a
20% TSP[c]	11.8b	4.6c	6.9b	6.3b	9.8ab	4.1bc	109.1b	30.1b
30% TSP	5.0c	9.1ab	7.4b	5.7b	12.3a	7.1b	82.1c	0.6d
20% SC	2.7c	4.1c	2.0c	4.9b	6.1bc	4.0bc	45.7d	10.6c
30% SC	2.9c	5.2bc	0.6c	1.2c	4.4c	2.7c	24.4e	2.6d

[a] Means within a column followed by the same letter are not significantly different ($P < 0.05$) (Duncan, 1955). Each value is the mean of 36 determinations.
[b] Relative intensities reported as area under the peak in 0.1 cm^2.
[c] TSP—Textured soy protein; SC—Soy concentrate.

ditions, endpoint temperatures were 1–2 degrees lower for ground beef containing added soy than for all-beef patties. They, Judge et al. (1974) and Anderson and Lind (1975) also reported that moisture and fat losses during cooking were affected by the soy additives. The addition of soy protein to beef patties significantly changed ($P < 0.001$) the electrophoretic patterns of the cooked patties (Table 1), and the intensity of seven bands was significantly ($P < 0.05$) reduced by either soy protein at both concentrations (Table 3). Band 5 did not follow the same pattern. The intensity of band 5 differed significantly between 30% SC and the all-beef samples, but not between the all-beef and any of the other samples.

For every band but 8 (Table 3), both levels of SC reduced intensities more than corresponding levels of TSP; some of those differences were significant ($P < 0.05$).

From our present data, we could not determine whether the reduction in band intensity associated with the addition of soy protein was due to increased loss of soluble protein with the cooking juices or to co-denaturation of the soy proteins with the beef proteins. Kotula and Rough (1975) stated "Beef-soy patties formulated with SC lost more weight during cooking than patties formulated with TSP but less than all-beef patties. Whereas, beef-soy patties formulated with TSP lost more fat and less moisture to cooking juices than all-beef patties, beef-soy patties with SC lost more moisture and less fat to the cooking juices than the all-beef patties." That relationship, suggests that more soluble proteins might have been lost with the greater volume of cooking juices from the SC patties, than from the TSP patties. That hypothesis might explain why the bands were less intense for SC than for TSP patties. That hypothesis however, would not explain why band intensities were lower for TSP than for all-beef patties which lost more moisture during cooking, and thus should have had less dense bands.

To explain the denaturation of myoglobin at a lower temperature with than without the presence of other protein in solution, Bernofsky et al. (1959) hypothesized that myoglobin co-denatures with other water-soluble protein from meat. Such co-denaturation of the soluble meat proteins with the soluble soy proteins might explain the decrease in band intensity associated with the addition of soy protein to beef.

When TSP and SC were incorporated into beef patties which were then cooked to different degrees of doneness, band intensities were decreased by both temperature increase and the addition of soy protein (Fig. 3 and 4).

Data in Table 4 indicate that SDS acrylamide gel electrophoresis might be used for estimating the maximum temperature to which beef has been cooked, as reported by Lee et al. (1974), for beef when discrete temperature differences of only a few degrees are not important. The influence of SC on loss of intensity for bands 7 and 8 was greater for the rare patties than for the all-beef patties cooked to the "well" degree of doneness. Lee et al. (1974) suggested that, in their electro-

— *Continued on page 746*

Table 4—Mean electrophoretic band intensity of beef-soy patties as influenced by the interaction of doneness and soy protein[a]

	Band[b]							
Treatment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Rare (58°C)								
Beef	37.7a	21.1ab	20.0a	29.3a	19.4a	16.0ab	170.9a	56.1b
20% TSP[c]	25.6b	14.7bc	19.8a	21.2b	17.3ab	9.4bc	162.7a	38.0c-e
30% TSP	12.4d-e	24.3a	12.2b	11.6c	17.1ab	14.8ab	119.9bc	1.4h
20% SC	7.1d-g	9.8c-e	4.4c-e	10.7cd	12.4a-d	4.3cd	72.4d-g	22.4e-g
30% SC	2.6g	10.1c-e	2.6de	3.1de	10.8b-f	5.1cd	38.8g-j	5.3gh
Medium rare (62°C)								
Beef	24.0bc	10.8cd	8.6b-d	11.1cd	6.1d-g	14.9ab	134.9ab	51.7bc
20% TSP	2.7fg	1.2de	2.7de	1.4e	3.4e-g	0d	86.6c-f	16.8f-h
30% TSP	6.4e-g	5.6c-e	11.1bc	7.0c-e	15.6a-c	9.1bc	92.2c-e	0h
20% SC	3.1fg	0.4e	2.0de	1.2e	4.1d-g	5.2cd	53.0f-j	8.0gh
30% SC	3.6fg	2.4de	0e	0e	5.6d-g	3.0cd	18.3ij	1.2h
Medium well (66°C)								
Beef	15.9cd	14.1bc	8.8b-d	8.6c-e	6.7d-g	17.9a	142.7ab	81.7a
20% TSP	13.6de	1.6de	5.3c-e	1.1e	10.9b-f	1.4cd	106.3b-d	33.9d-f
30% TSP	0g	1.1de	3.7de	3.0de	11.0b-e	2.2cd	60.3e-h	0h
20% SC	0g	1.8de	0e	4.1c-e	8.0c-g	5.0cd	28.3h-j	7.1gh
30% SC	4.2e-g	3.0de	0e	0e	1.2g	2.7cd	23.9h-j	2.1h
Well (68°C)								
Beef	4.0fg	5.7c-e	6.3b-e	1.4e	2.2fg	9.7bc	93.3c-e	50.4b-d
20% TSP	5.2e-g	1.1de	0e	1.6e	7.6c-g	5.3cd	80.9d-f	31.7ef
30% TSP	1.0g	1.4de	2.6de	1.3e	5.3d-g	2.1cd	56.1e-i	1.1h
20% SC	0.6g	4.4de	1.7de	3.6c-e	0g	1.4cd	28.9h-j	4.8gh
30% SC	1.4g	5.1c-e	0e	1.5e	0g	0cd	16.8j	1.9h

[a] Means within a column followed by the same letter are not significantly different ($P < 0.05$) (Duncan, 1955). Each value is the mean of nine determinations.

[b] Relative intensities reported as area under the peak in 0.1 cm^2.

[c] TSP—Textured soy protein; SC—Soy concentrate.

phoretic method, reduction of the number of distinct protein bands to four or less indicated that beef had been cooked to 70°C and thus ensured the inactivation of the foot-and-mouth disease virus. Figures 3 and 4 show electrophoretic patterns of beef-soy patties with fewer than four protein bands for the patties that had been cooked to endpoints ranging from 58–68°C. Thus the procedure of Lee et al. (1974), which apparently was effective for all-beef products in casings, should not be extrapolated for use with meat products to which other proteins such as soy have been added.

Effects should be determined of other potential meat additives (casein, whey, peanuts, cottonseed and water) on the electrophoretic patterns of the fabricated products during cooking.

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Mention of product names does not imply endorsement by the United States Government.

holding bin between the fine grinder and the packaging machine, making a total of 16 production line (0-time) samples. The production line samples were analyzed in a mobile microbiology laboratory parked beside the meat plant. Eighteen chub packs were collected from each batch (total, 144 chub packs) for storage so that three chub packs from each batch were available for sampling after 3, 6, 9, 12, 15, and 18 days of storage at -1.7 ± 0.6 C.

The 11-g samples obtained before packaging (0-time) were blended 2 min in 99 ml of sterile phosphate-buffered diluent (pH 7). Three locations were sampled aseptically within each chub pack to obtain a 25-g sample that was blended 2 min in 225 ml of sterile phosphate-buffered diluent. Serial dilutions of the samples were plated in duplicate on plate count agar (Difco Laboratories, Detroit, Mich.) in cluster dishes. Plates for total aerobic bacterial counts were incubated 48 h at 35 C, and plates for psychrotrophic bacterial counts were incubated 10 days at 5 C.

Coliforms, *Escherichia coli*, and *Staphylococcus aureus* were enumerated according to the methods described in the Microbiology Laboratory Guidebook (12). All EC broth (Baltimore Biological Laboratory, Cockeysville, Md.) tubes showing gas after 24 h at 45.5 C were streaked onto Levine eosin methylene blue agar (BBL) for detection of typical *E. coli* colonies.

C. perfringens was isolated by inoculating one tube of neutral red cooked meat (NRCM) medium from each of the serial dilutions of the samples in phosphate buffer. Each tube of NRCM medium contained about 1.0 g of cooked meat medium (Difco) plus 8 ml of NRCM diluent (10.0 g of tryptone [Difco]; 1.0 g of sodium thioglycolate; 1.0 g of soluble starch [Difco]; 2.0 g of dextrose; 5 ml of a 1% solution of neutral red [Difco] dissolved in 60% ethanol; and 1 liter of distilled water). Presumptive positive tubes of NRCM were those that turned yellow after 24 h at 35 C. Any red tubes were held 3 days before they were recorded as negative. From each positive tube of NRCM, a tube of peptone colloid medium (Difco) was inoculated (1 ml) and incubated 24 h at 35 C. From each inoculated peptone colloid tube, a tube of Strong sporulation medium (4.0 g of yeast extract [Difco]; 15.0 g of proteose peptone no. 3 [Difco]; 4.0 g of soluble starch [Difco]; 1.0 g of sodium thioglycolate; 10.0 g of Na_2HPO_4; 0.5 g of Norit A [J. T. Baker Chemical Co., Phillipsburg, N.J.]; and 1 liter of distilled water) was inoculated (1 ml) and incubated 24 h at 35 C. From each tube of previously inoculated Strong sporulation medium, 1 ml was then pipetted into tubes containing 1.0 ml filtered 100% ethanol. The alcohol tubes were shaken and left at room temperature for 1 to 2 h, then 0.1 ml of the alcohol mixture from each tube was pipetted onto plates of sulfite polymyxin sulfadiazine agar (SPS; Difco) containing 1.0 ml of ferric ammonium citrate solution (34.0 g of anhydrous sodium thiosulfate, 4.0 g of ferric ammonium citrate, and 100 ml of distilled water) per 100 ml of SPS agar. The plates were streaked for isolation, caped with an additional 5 to 7 ml of agar, and incubated in GasPak 100 anaerobic systems (BBL) for 48 h at 35 C. Two typical black colonies were picked from each SPS plate for confirmation tests. Each colony was used to inoculate a tube of indole-nitrite medium (BBL) and a tube of motility-nitrite medium (25 g of indole-nitrite medium, 2 g of agar, and 1 liter of distilled water). The tubes were incubated for 48 h at 35 C, then examined for motility, indole production (with Kovac reagent), and nitrate reduction (with sulfanilic acid reagent and α-naphthylamine reagent). Gram-positive rods which were nonmotile, indole negative, and nitrate positive were considered to be *C. perfringens*.

RESULTS

The bacterial contents of the raw ground beef before and after storage at -1.7 ± 0.6 C are summarized in Table 1. Initial mean $\log_{10}$ counts for total aerobic and psychrotrophic bacteria in the ground beef samples were 4.60/g and 4.86/g, respectively. Total aerobic and psychrotrophic bacterial counts after 3 and 6 days of storage were significantly ($P \le 0.05$) lower than the initial counts, but the magnitude of the differences was of questionable importance. However, the counts increased significantly ($P \le 0.05$) after 9, 12, 15, and 18 days of storage.

TABLE 1. *Mean $\log_{10}$ counts[a] of selected bacteria in raw ground beef stored at -1.7 ± 0.6 C*

Storage day	Bacteria/g					
	Total aerobes	Psychrotrophs	Coliforms	*E. coli*	*S. aureus*	*C. perfringens*
0	4.60d[b]	4.86cd	1.70a	1.24a	0.74a	0.22b
3	4.48e	4.59e	1.47ab	1.13ab	0.67a	0.45ab
6	4.48e	4.63e	1.26bc	1.07ab	0.52a	0.46ab
9	4.64d	4.78d	1.09c	0.90b	0.65a	0.70a
12	4.89c	4.95c	1.10c	0.82b	0.58a	0.52ab
15	5.18b	5.18b	1.21bc	1.00ab	0.75a	0.37ab
18	5.53a	5.52a	1.22bc	1.04ab	0.53a	0.38ab

[a] Values for storage day 0 are mean $\log_{10}$ counts of 16 samples; all other values are mean $\log_{10}$ counts of 24 samples.

[b] Values in the same column followed by different letters are significantly ($P \le 0.05$) different according to Duncan's multiple-range test (2).

There was a 1 log increase in total aerobes and psychrotrophs per gram of ground beef between 3 and 18 days of storage. The initial mean $\log_{10}$ coliform count in the ground beef was 1.70/g. A significant ($P \leq 0.05$) reduction in the initial number of viable coliforms was evident after 6, 9, 12, 15, and 18 days of storage at -1.7 ± 0.6 C. Mean $\log_{10}$ counts of *E. coli* decreased, although not significantly, from an initial count of 1.24/g to 1.04/g after 18 days of storage. Coagulase-positive *S. aureus* and *C. perfringens* counts did not change significantly during storage. Figure 1 depicts graphically the effects of storing ground beef at -1.7 ± 0.6 C on the viability of total aerobes, psychrotrophs, coliforms, *E. coli*, *S. aureus*, and *C. perfringens* present in the meat. The appearance and odor of the 18-day-old ground beef chub packs further indicated that they were edible.

The distributions of the bacterial counts in the ground beef samples are shown in Tables 2 and 3. At the time of manufacture, all of the ground beef samples had aerobic plate counts of 10^6 or fewer/g, and 94% of the samples contained 10^5 or fewer total aerobic bacteria/g. All of the samples had initial psychrotrophic bacterial counts of 10^6 or fewer/g, and 50% contained 10^5 or fewer psychrotrophs/g. Total aerobic and psychrotrophic bacterial counts did not exceed 10^6/g until 18 days of storage, when 17% of the samples had total aerobic counts between 10^6 and 10^7/g and 25% had psychrotrophic counts between 10^6 and 10^7/g.

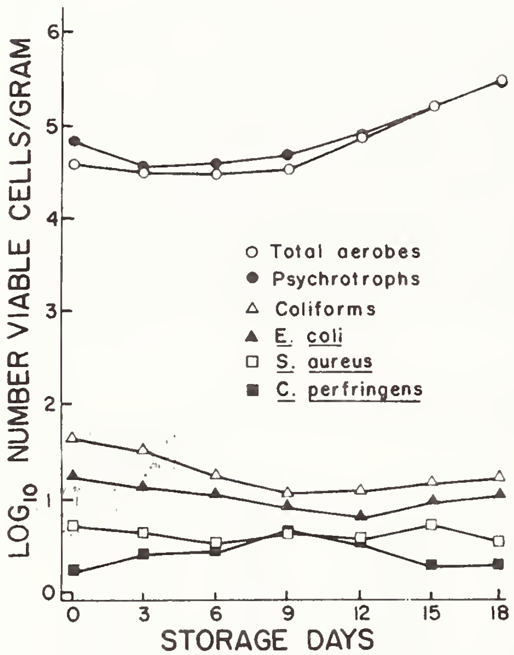

FIG. 1. *Effects of storage at -1.7 ± 0.6 C for 18 days on the microbiological quality of ground beef. Values for storage day 0 are mean $\log_{10}$ counts of 16 samples; all other values are mean $\log_{10}$ counts of 24 samples.*

TABLE 2. *Distribution of total aerobic and psychrotrophic bacterial counts (per gram) in raw ground beef stored at -1.7 ± 0.6 C*

Bacteria	Storage day	No. of samples[a] with bacterial counts			
		$>10^3$ to 10^4	$>10^4$ to 10^5	$>10^5$ to 10^6	$>10^6$ to 10^7
Total aerobes	0	1	14	1	
	3	3	19	2	
	6	3	20	1	
	9		22	2	
	12		16	8	
	15		8	16	
	18		4	16	4
Psychrotrophs	0	2	6	8	
	3	3	17	4	
	6	4	13	7	
	9	3	13	8	
	12		12	12	
	15		7	17	
	18		5	13	6

[a] Samples for each storage day represent eight batches (4 days × two batches) of ground beef.

At the time of manufacture, 81% of the samples contained 100 or fewer coliforms/g; 94% contained 100 or fewer *E. coli*/g; and 100% contained 100 or fewer *S. aureus* and *C. perfringens*/g (Table 3). By the laboratory methods employed in this study, 19% of the samples contained less than 10 coliforms/g at the time of manufacture; 31% contained less than 10 *E. coli*/g; 50% contained less than 10 *S. aureus*/g; and 81% contained less than 10 *C. perfringens*/g. These counts either decreased or remained relatively unchanged throughout the storage period (Fig. 1).

DISCUSSION

The Oregon microbiological standards state that fresh or frozen meat products should not contain more than 5 million microorganisms/g or 50 *E. coli*/g (R. W. Johnston, Meat Industry Res. Conf., Univ. of Chicago, Chicago, Ill., 20–21 March 1975). None of the ground beef samples evaluated in this study exceeded the Oregon standard for total bacterial counts, even after 18 days of storage at -1.7 ± 0.6 C. However, 15% of the samples (seven production line samples and five 3-day, three 6-day, one 9-day, one 12-day, four 15-day, and three 18-day chub packs) exceeded 50 *E. coli*/g. The incidence and

TABLE 3. *Distribution of counts (per gram) of selected bacteria in raw ground beef stored at −1.7 ± 0.6 C*

Bacteria	Storage day	No. of samples[a] with bacterial counts			
		$<10^1$	10^1 to 10^2	$>10^2$ to 10^3	$>10^3$ to 10^4
Coliforms	0	3	10	3	
	3	10	7	6	1
	6	10	11	3	
	9	13	9	2	
	12	15	6	3	
	15	14	5	4	1
	18	14	4	6	
E. coli	0	5	10	1	
	3	13	6	5	
	6	13	8	3	
	9	14	9	1	
	12	18	5	1	
	15	16	4	4	
	18	15	6	3	
S. aureus	0	8	8		
	3	20	4		
	6	22	2		
	9	21	2	1	
	12	23	1		
	15	17	6	1	
	18	20	4		
C. perfringens	0	13	3		
	3	21	3		
	6	19	5		
	9	20	1	2	1
	12	19	4	1	
	15	22	2		
	18	22	1	1	

[a] Samples for each storage day represent eight batches (4 days × two batches) of ground beef.

behavior of *E. coli*, *S. aureus* and *C. perfringens* in the ground beef used in this study were similar to those previously published (3, 4). The increased interest in the establishment of microbiological standards for meat products suggests that the sources of those food-borne pathogens should be studied further to reduce their numbers in the ground beef supply.

Other investigators have reported that some raw ground beef collected at retail markets may have high bacterial counts. Rogers and McCleskey (7) found bacterial counts in excess of 10^7/g in ground beef from 16 of 24 retail markets. Coliform counts varied widely among samples (20 to 1,100,000/g), and no marked correlation was noted between coliform and plate counts. Rao (6) reported that standard plate counts were 11,000 to 36,533,000/g and coliform counts were 233 to 71,333/g on 15 ground beef samples taken from a retail market. There was no relationship between coliform counts and plate counts. Law et al. (5) found that the bacterial population of 32 ground beef samples from 16 retail stores varied from 1.9×10^6 to 4.6×10^8/g. Duitschaever et al. (1) reported that 64% of 213 retail ground beef samples had aerobic plate counts in excess of 10^7/g and some in excess of 10^8/g.

Surkiewicz et al. (8) conducted a bacteriological survey of raw beef patties collected from 42 federally inspected establishments. At the time of manufacture, 76% of 74 sets of raw beef patties had aerobic plate counts of 10^6 or fewer/g; 84% contained 100 or fewer coliforms/g; 92% contained 100 or fewer *E. coli*/g; and 85% contained 100 or fewer *S. aureus*/g. Salmonellae were isolated from only 3 (0.4%) of 735 beef patties.

Our study showed that by use of proven sanitary practices ground beef of good bacteriological quality can be produced commercially. Modern advances in sanitation and refrigeration allow no excuse for high bacterial counts in ground beef offered to the consumer at the retail level. Ground beef is normally exposed to refrigerated temperatures of 35 to 40 F (1.67 to 4.44 C) during distribution and display. Such temperatures result in shorter generation times for psychrotrophic bacteria (9) than the temperature used in this study. Our data indicate that meat processors, wholesalers, and retailers could improve the bacteriological quality and prolong the shelf life of ground beef packaged in oxygen-impermeable film if the temperature of the product never exceeded −1.7 ± 0.6 C.

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EVALUATION OF BEEF PATTIES CONTAINING SOY PROTEIN, DURING 12-MONTH FROZEN STORAGE

ABSTRACT

Patties containing 20 or 30% of soy protein (textured or concentrate) were stored at −17°C and evaluated tri-monthly for 1 yr for effects of storage on organoleptic properties and chemical changes. Textured soy proteins from four manufacturers and concentrate from two manufacturers were tested. Fat content was about 20% for all patties. A 52-member panel of adults, from 18–60 yr of age, evaluated (without condiments) the 12 types of patties with soy and the all-meat patties. A 13-member panel evaluated the effects of condiments on acceptability. Chemical tests included proximate analysis (ash, fat, moisture and protein), pH, peroxide values and thiobarbituric acid (TBA) number. Mean scores for flavor, aroma and overall acceptability of the patties did not change significantly during the year of frozen storage. Some differences were significant in scores for tenderness, appearance and juiciness, but they were too small to be of practical importance. The addition of condiments to patties did not improve the scores for appearance and juiciness but did improve scores for flavor, aroma, tenderness and overall acceptability. Throughout the year, patties containing soy concentrate at either 20 or 30% rated significantly lower than most of the patties containing textured soy protein and the all-beef patties when evaluated for flavor, appearance, aroma and overall acceptability. Although compositional changes in patties were evident during 12 months of storage, their magnitudes were inconsequential. Peroxide and TBA values increased during storage at a faster rate for all-beef patties than for patties containing soy protein. Some panelists were able to detect old or rancid condition in some products during the 9- and 12-month storage but most palatability traits were not significantly different in patties that had been stored for up to 12 months. Soy protein additives tended to inhibit rancidity development.

INTRODUCTION

BEEF PATTIES are used extensively by the Armed Forces to provide high quality protein in a form that is generally acceptable to civilian and military personnel. In order for the Armed Forces to benefit from the addition of soy protein to meat, the resulting product has to be capable of withstanding 9-month frozen storage without adverse chemical or palatability changes. Huffman and Powell (1970) reported that patties containing 2% soy product were better than patties containing all-beef. Information has not been reported on acceptability of patties containing soy protein products at 20 or 30% levels after several months of frozen storage.

The objective of this research was to investigate the acceptability of beef patties containing soy protein to persons of military age. Interest was directed toward evaluation of patties containing added soy protein at levels that include present upper limits of addition for use by the School Lunch Program (Food and Nutrition Service Notice 219). The influence of condiments on the acceptability of cooked patties containing soy protein was also evaluated. A secondary objective was to investigate changes in moisture content, peroxide and TBA values during frozen storage of beef patties containing soy proteins. The chemical composition of soy protein and beef patties containing soy protein was also investigated.

EXPERIMENTAL

Patty fabrication

Twelve lots of 85g beef patties, six containing 20% and six containing 30% hydrated soy protein, were prepared at a commercial meat processing plant from textured vegetable protein from four manufacturers (A, B, C, D) and soy concentrates from two manufacturers (E, F). All soy proteins were dehydrated, vitamin enriched and contained no flavor additives, but they differed in physical appearance. Particle size ranged from 16–50 mesh for brand F to 2½–9 mesh for brand C. Beef patties (about 228.6 kg) containing hydrated soy protein were formulated for each lot according to recommendations of the USDA Food and Nutrition Service Notice 219: for the School Lunch Program (1971).

As a control, a 453.6 kg lot of all-beef (80% lean/20% fat) patties was prepared. Meat for producing all lots of beef patties was obtained from USDA Good Grade triangle beef (chuck, brisket, plate) in accordance with Military Specification Mil-B-003854F. In order to maintain fat content at approximately 20% in all patties, the beef for formulating patties at the 20% level of hydrated soy protein contained approximately 25% fat; whereas, meat used for fabricating patties having 30% hydrated soy protein, initially contained approximately 30% fat. The meat used for the all-beef patties contained 20.5% fat.

The specified quantity of meat for each lot, as listed above, was ground through a 2.54 cm plate. The Hobart fat tester and a chemical method of Bittenbender (1970) were both used for determination of fat in samples taken at random from each lot. Adjustments were made on the percentage of fat in each lot, by correcting with 50/50 trim, or 80/20 triangle, and fat determinations were again made to ensure proper fat content. Meat for all lots was stored overnight in coolers to maintain meat temperature at −2 to 0°C.

Hydration

All soy proteins were hydrated at least 10 min according to manufacturer's suggestions for their particular product with tap water (16°C). Proportion of water was 1.5:1 for textured soy protein and 2.5:1 for soy concentrate. Products C, D and F were hydrated in meat trucks for about 15 min in accordance with manufacturer's recommendations. Appropriate quantities of coarse ground meat and hydrated soy protein were alternately added to a mixer and blended for about 3 min. Products A, B and E were hydrated for 10 min in the mixer then meat was added and the ingredients mixed for 5 min.

Packaging and storage

Each lot of the meat-hydrated soy protein mixture was ground through a double screw 3.2 mm plate grinder, then carried on a conveyor to a Hollymatic patty machine which formed the mix into 85g patties.

The patties were packed into 47.6 cm × 33 cm × 16.2 cm boxes which met Military requirements for overseas shipment (Federal Specifications: PPP-B-636c and L-P-378c; and Military Standard-129E). Individual patties were separated by moisture vapor proof paper. A sheet of moisture vapor proof paper was placed on top of the stacks, and another 12 stacks of patties were added. The plastic liner was then folded back to cover those patties, and the boxes were sealed. Each box contained 168 patties with a net weight of 14.3 kg. All packed boxes were frozen in air blast at −25°C and stored about 3 days at −17°C until shipped to the laboratory for long term storage at −17°C as indicated in the experimental design.

Table 1—Flavor of patties, without condiments, evaluated by a 52-member consumer panel[a]

Product	Months storage 0	3	6	9	12
			20% level		
Textured					
A	5.5a	5.5ab	5.6ab	5.2abcd	5.2ab
B	4.8abcd	5.6a	5.9a	5.7ab	5.3a
C	5.3ab	4.5cde	5.3abc	5.4abc	5.5a
D	4.8abcd	5.7a	5.6ab	5.1bcde	5.5a
Concentrates					
E	4.0def	3.6f	4.2de	4.3efg	3.8c
F	4.0def	4.1def	4.1de	4.4def	4.7abc
			30% level		
Textured					
A	5.0abc	4.9abcd	4.8bcd	5.4abc	5.5a
B	4.5bcd	4.2def	4.5cde	5.2abcd	4.7abc
C	4.7abcd	5.6ab	4.9bcd	4.6cdef	4.9ab
D	4.3cde	4.7bcde	4.6cd	5.3abc	4.7abc
Concentrates					
E	3.6ef	3.8ef	3.7e	3.5g	4.3bc
F	3.3f	3.6f	3.6e	4.0fg	3.9c
All-beef	5.4a	5.1abc	6.0a	6.0a	5.6a

[a] Values within a column followed by the same letter or letters were not significantly different ($P < 0.05$) according to analysis of variance and Duncan's Multiple Range Test (1955). Each value is based on 32 determinations. Scores were based on a 9-point hedonic scale, 1 — poorest, 9 — best.

Table 2—Appearance of patties, without condiments, evaluated by a 52-member consumer panel[a]

Product	Months storage 0	3	6	9	12
			20% level		
Textured					
A	5.9a	5.9a	5.9a	6.2a	5.9ab
B	5.4ab	6.1ab	6.1a	6.0ab	5.9ab
C	5.5ab	6.0ab	5.5ab	6.1ab	6.3a
D	5.3abc	5.7ab	4.7a	5.8ab	5.2bcd
Concentrates					
E	5.1abc	4.8de	4.8bcd	5.6ab	5.2bcd
F	4.7cd	5.4bcd	5.3abc	5.6ab	5.4abc
			30% level		
Textured					
A	5.5ab	5.8ab	5.6a	6.0ab	5.6abc
B	5.8a	5.6bc	5.8a	5.8ab	5.9ab
C	5.5ab	6.3a	5.8a	6.0ab	5.6abc
D	4.8bcd	4.9cde	4.7cd	5.4bc	4.5d
Concentrates					
E	4.4d	4.2f	4.5d	4.2d	4.9cd
F	4.7cd	4.6ef	4.4d	4.9c	4.5d
All-beef	5.7a	5.5bc	5.9a	6.2a	5.6abc

[a] Values within a column followed by the same letter or letters were not significantly different ($P < 0.05$) according to analysis of variance and Duncan's Multiple Range Test (1955). Each value is based on 32 determinations. Scores were based on a 9-point hedonic scale, 1 — poorest, 9 — best.

Organoleptic evaluation

Samples, selected randomly from each lot, were evaluated by a panel, composed of 52 adults at intervals of 0, 3, 6, 9 and 12 months. Patties were cooked from the frozen state on a Hotpoint (230 watt) griddle at 177°C for 3 min on each side. This time-temperature resulted in the degree of doneness at which the final pinkness at the center of the all-beef patties disappeared. The patties were removed from the griddle, quartered, randomly placed on a plate according to Plan 11.22 of Cochran and Cox (1957), and served to the panelists for evaluation. No condiments were added to the patties. Discussion of patties by panelists during evaluation was not permitted. Panelists evaluated each quarter for tenderness, flavor, appearance, aroma, juiciness, and overall acceptability.

A second panel of 13 USDA employees was convened. The specific objective of this panel was to determine the effect of condiments on taste panel evaluation of the patties. Consequently, patties were served on the first day without condiments as in the evening panels, while patties on the second day were cooked with monosodium glutamate, salt and pepper, and served on a bun with pickles, mustard and catsup; cola and potato chips were also given to the panelists. Cooking, sampling and evaluation procedures were the same as for the evening panel.

Chemical analysis of patties

Proximate analysis of patties from each lot was conducted after 0, 3, 6, 9 and 12 months storage. Samples, selected randomly, were homogenized in a blender for 2 min and prepared according to AOAC (23.001) (1965). Analyses were completed following AOAC procedures for moisture (23.003), ash (29.012), fat (23.005), protein (23.009), and peroxide value (26.024 and 26.025). In addition, the thiobarbituric acid test (TBA) for rancidity, was conducted by a distillation method of Tarladgis et al. (1960). The pH of patties blended in distilled water was determined with a Beckman Expandamatic pH Meter.

RESULTS & DISCUSSION

Organoleptic evaluation — 52-member panel

Patties without condiments. *Flavor.* Although all-beef patties had the highest average rating, scores for patties containing 20% textured protein were not significantly lower ($P < 0.05$). Scores for patties containing 30% soy protein were generally lower than corresponding patties with 20% soy additives, but the differences were not always significant. In many instances, patties containing soy concentrates were scored significantly lower ($P < 0.05$) than those containing textured proteins (Table 1).

Some panelists detected old or rancid flavor in the 9- and 12-month patties. Sessa (1974) found that phospholipids in soybeans such as phosphatidylcholine developed off-flavors when oxidized. The coefficient of correlation between TBA values and flavor scores was −0.63, indicating that lipid oxidation might have contributed to flavor differences.

Overall, flavor was best in the all-beef patties, followed by patties containing textured soy protein at 20%, then 30%. Soy protein concentrate patties at 20% were still less flavorful and patties containing 30% soy protein concentrate were least flavorful. The differences in acceptability of flavor of the 13 types of patties appeared to be similar for all storage periods.

Appearance. Patties with 30% soy protein were generally scored lower than patties containing 20%, but the differences were only significant for concentrates (Table 2). Patties containing textured soy protein product D were rated consistently lower than the other patties with textured protein, and at the 30% level of addition to patties the difference was significant ($P < 0.05$). Patties with soy concentrates were significantly lower ($P < 0.05$) than patties with textured soy protein. Particle size, again, might be a factor in the lower scores for concentrates, which were finer and gave the patty a grainy appearance.

Aroma. Aroma of patties containing textured soy proteins varied little, even between 30% and 20% (Table 3). Patties containing concentrates usually scored lower in aroma than textured and all-beef patties. This difference was often significant ($P < 0.05$) when patties contained 30% concentrate. Patties with 20% concentrate sometimes scored significantly

Table 3–Aroma of patties, without condiments, evaluated by a 52-member consumer panel[e]

Product	Months storage 0	3	6	9	12
		20% level			
Textured					
A	6.0a	5.7ab	5.7a	5.7a	5.9a
B	5.3abcdef	5.6ab	6.1a	5.7a	5.5ab
C	5.9ab	5.6ab	5.7a	5.8a	6.0a
D	5.6abc	5.7ab	5.6a	5.5ab	5.6ab
Concentrates					
E	4.8def	5.1bc	4.7bc	5.3ab	4.7cd
F	4.8def	5.1bc	4.9bc	4.9bc	5.0bcd
		30% level			
Textured					
A	5.2bcdef	5.4ab	5.5ab	5.7a	5.9a
B	5.5abcd	5.2abc	5.4ab	5.7a	5.7ab
C	5.4abcde	5.9a	5.8a	5.5ab	5.5ab
D	5.0cdef	5.2bc	5.4ab	5.5ab	5.0bcd
Concentrates					
E	4.9cdef	3.9d	4.4c	4.2d	5.0bcd
F	4.6f	4.5cd	4.4c	4.3cd	4.5d
All-beef	5.5abcd	5.3ab	6.0a	6.0ab	5.4abc

[1] Values within e column followed by the seme letter or letters were not significently different ($P < 0.05$) according to enelysis of variance end Duncan's Multiple Renge Test (1955). Each value is based on 32 determinetions. Scores were besed on e 9-point hedonic scele, 1 – poorest, 9 – best.

Teble 4–Juiciness of patties, without condiments, evaluated by a 52-member consumer panel[e]

Product	Months storage 0	3	6	9	12
		20% level			
Textured					
A	5.6a	5.1cde	5.6ab	5.0bc	5.4ab
B	4.7bcde	5.3bcd	5.4ab	5.2bc	5.2abc
C	5.0abcd	4.9de	5.7a	5.3bc	5.6ab
D	4.7bcde	6.0ab	5.1abc	4.8bcd	4.8bcd
Concentrates					
E	4.3def	4.5ef	4.6cd	4.6cd	4.3d
F	4.2ef	4.4ef	3.8e	4.7bcd	5.1bcd
		30% level			
Textured					
A	5.1abc	5.8abc	5.6a	6.1a	6.0a
B	5.1abc	5.8abc	5.3abc	5.5ab	5.4ab
C	5.0abcd	6.1a	5.7a	5.3bc	5.6ab
D	5.2ab	5.4abcd	4.9bc	5.0bc	5.6ab
Concentrates					
E	3.7f	4.3ef	4.8bc	4.7bcd	4.5cd
F	3.6f	4.0f	4.0de	4.2d	4.3d
All-beef	4.3def	4.8de	4.9bc	4.7bcd	5.6ab

[e] Values within e column followed by the same letter or letters were not significently different ($P < 0.05$) according to enalysis of verience end Duncan's Multiple Renge Test (1955). Eech value is based on 32 deteminetions. Scores were besed on e 9-point hedonic scele, 1 – poorest, 9 – best.

lower ($P < 0.05$) in aroma than textured or all-beef patties.

Juiciness. Patties containing textured soy protein consistently appeared to be more juicy than the all-beef patties or the patties with concentrates. Differences between all-beef and soy concentrate patties, though sometimes significant, were not of sufficient magnitude to be meaningful (Table 4).

Tenderness. Patties with 30% textured protein, then 20%, had the highest scores, followed by concentrates at 30% then 20% (Table 5). All-beef patties had the lowest average rating (4.1). The most desirable degree of tenderness might have been exceeded with the addition of the higher levels of soy protein. In some instances the patties became too crumbly and though evaluated as being tender would be rated lower in acceptability.

These data suggest that cooking losses differed between patties, since all-beef patties were observed to shrink more than patties containing soy additivies. Judge et al. (1974) reported that shrinkage in patties was substantially reduced by soy additives. The effect of soy additives on cooking losses was also reported by Kotula and Rough (1975) and Drake et al. (1975).

Overall acceptability. All-beef patties and patties with textured soy protein usually were rated significantly higher ($P < 0.05$) than patties with concentrates (Table 6). On the average, patties with 30% soy protein were scored lower than the corresponding patty with 20% soy protein, but the differences were not always significant ($P < 0.05$). Though some panelists were able to detect old condition rancidity in beef patties after 9 and 12 months storage, the all-beef patties were rated about as good as, or better than the other patties tested.

The effect of storage on organoleptic quality. Average tri-monthly scores for palatability traits are summarized in Table 7. None of the traits rated decreased in score. This supports chemical data which demonstrated no important chemical decomposition during the year of storage. Although TBA values steadily increased with storage, only a few panelists could detect rancidity in the cooked patties. Six panelists reported on old or rancid flavor in patties stored 12 months. A few panelists evaluating the patties after 9 months commented that the patties had exceeded their shelf life. Scores for some traits increased during storage.

Organoleptic evaluation – 13-member panel

Effects of condiments on palatability traits of patties are presented in Table 8. Scores for flavor, aroma, tenderness and overall acceptability were significantly higher for patties served with condiments than patties served without. Differences in appearance were not significant ($P < 0.05$). Scores for juiciness were somewhat lower for patties served with condiments, possibly because the bun absorbed the juices.

Chemical analyses of soy proteins

The chemical composition of the soy protein products (Table 9) was similar to that reported by Batcher et al. (1971). However, ash, crude fiber, fat and protein appear higher because these values are reported on a moisture free basis. If reported on a moisture present basis the percent protein for products A through F would be 53.82, 49.47, 49.90, 52.16, 65.10, and 64.52 respectively.

Chemical analyses of fabricated patties

Fabricated patties were analyzed tri-monthly to ensure that patties evaluated for palatability and acceptance by the panels were substantially the same in proximate composition throughout the evaluation periods. The analyses also provide input into the nutritional data bank.

Ash. Patties containing concentrated soy protein and all-beef patties generally had lower ash contents than patties containing textured soy products (Table 10). Ash content was higher in patties with 30% soy protein than in those with 20%. This simply reflected the increase in soy protein, which had a higher concentration of ash than the beef which the protein

Table 5—Tenderness of patties, without condiments, evaluated by a 52-member consumer panel[a]

Product	Months storage 0	3	6	9	12
	20% level				
Textured					
A	6.3a	5.3bcd	5.6abc	5.4bc	5.4bcd
B	4.8d	5.4bcd	5.8abc	5.3bcd	4.7ef
C	5.3bc	5.8ab	5.7abc	5.0cd	5.2bcde
D	4.8cd	5.7abc	5.6abc	5.1bcd	4.8def
Concentrates					
E	4.6d	5.2bcd	4.7de	4.8cd	4.9cdef
F	4.5de	4.2e	4.1e	4.6de	4.6ef
	30% level				
Textured					
A	5.9ab	5.9ab	6.3ab	6.2a	6.4a
B	6.0ab	6.4a	6.4a	6.5a	6.0ab
C	6.1a	6.4a	6.1abc	5.1cd	5.7abcd
D	5.9ab	6.5a	5.4cd	5.9ab	5.8abc
Concentrates					
E	5.6ab	5.0cd	5.8abc	5.0cd	5.2bcde
F	4.8cd	4.6de	4.7de	4.1ef	4.1f
All-beef	3.8e	4.1e	4.6de	3.5f	4.3f

[a] Values within a column followed by the same letter or letters were not significantly different (P < 0.05) according to analysis of variance and Duncan's Multiple Range Test (1955). Each value is based on 32 determinations. Scores were based on a 9-point hedonic scale, 1 — poorest, 9 — best.

Table 6—Overall acceptability of patties, without condiments, evaluated by a 52-member consumer panel[a]

Product	Months storage 0	3	6	9	12
	20% level				
Textured					
A	5.1a	5.1a	5.4abc	5.0a	5.0ab
B	4.5abc	5.0ab	5.7a	5.2a	5.0ab
C	5.0a	4.6abc	5.0abc	4.8ab	5.4a
D	4.7a	5.3a	4.9abc	4.7ab	4.8abc
Concentrates					
E	3.8cd	4.0cd	3.9d	4.0bcd	3.9cd
F	3.8cd	4.0cd	3.9d	4.4abc	4.2bcd
	30% level				
Textured					
A	4.6ab	4.6abc	4.7bc	5.1a	5.4a
B	4.7a	4.1cd	4.7bc	5.1a	4.5abcd
C	4.3abc	5.1a	4.8bc	4.5abc	4.3bcd
D	3.9bcd	4.2bcd	4.7bc	4.9a	4.4abcd
Concentrates					
E	3.5d	3.7d	3.5d	3.3d	3.8d
F	3.4d	3.7d	3.4d	3.7cd	3.8d
All-beef	5.0a	4.7abc	5.5ab	5.1a	5.1ab

[a] Values within a column followed by the same letter or letters were not significantly different (P < 0.05) according to analysis of variance and Duncan's Multiple Range Test (1955). Each value is based on 32 determinations. Scores were based on a 9-point hedonic scale, 1 — poorest, 9 — best.

replaced. Based on data collected over all months, ash content ranged from 0.86% (F-20%) to 1.39% (A-30%), and probably had no effect on palatability traits.

Fat. During fabrication of patties, an attempt was made to maintain fat content relatively constant at 20.5% in all patties. However, on analyses of patties (Table 10) fat content over all months ranged from 18.37% (F-30%) to 23.41% (E-20%). These variations were attributed to differences between and within lots of beef used in formulation of the patties. More precise control of fat content in the patties was not possible under the commercial conditions used in the study. We did not analyze each patty served to the panelists, therefore, we cannot indicate with certainty that the magnitude of the fat content fluctuations did not affect palatability traits.

Moisture. Patties containing soy concentrates had a higher average content of moisture than the patties with textured soy (Table 10). This was expected because large volumes of water were used to hydrate the concentrates in accordance with normal usage. Moisture content over all months ranged from 54.77% (B-30%) to 61.41% (F-30%).

Protein. Protein content (Table 10) was relatively constant over all patties and ranged from 16.70% (C-30%) to 18.05% (all-beef).

pH. The patties containing 20 or 30% soy protein in general had a slightly higher pH than the all-beef or the patties from Brand F-Soy (Table 10). However, even when these differences were significant, the magnitude of the difference was of no immediate importance. The minimum value was 5.52 (F-30%); the maximum value, 6.25 (B-30%). Except for product F, all patties containing soy protein had a higher pH than the all-beef patties.

TBA number. Concentrations of malonaldehyde, as an index of rancidity in the patties, are shown in Table 11. The highest initial value was recorded for all-beef patties followed by product F-30% and 20%; the lowest was 0.5 for B-30%. Values for all months ranged from 0.47 to 5.47 (mg malonaldehyde/100-g sample). Differences in TBA number could not be explained by classification of data into textured and concentrates, or 20% and 30%.

Lecithin, a long established antioxidant, is often added

Table 7—Effect of storage on organoleptic traits of all frozen patties,[a] evaluated by a 52-member panel

Month in storage	Flavor	Appearance	Aroma	Juiciness	Tenderness	Overall acceptability
0	4.6b	5.2b	5.3a	4.6b	5.3ab	4.3b
3	4.7ab	5.4ab	5.2a	5.1a	5.4ab	4.5ab
6	4.8a	5.4ab	5.4a	5.0a	5.5a	4.6a
9	4.9a	5.7a	5.4a	5.0a	5.1b	4.6a
12	4.9a	5.4b	5.4a	5.2a	5.2b	4.6a

[a] Values within a column followed by the same letter or letters were not significantly different (P < 0.05) according to analysis of variance and Duncan's Multiple Range Test (1955). Each value is based on 512 observations. Scores were based on a 9-point hedonic scale, 1 — poorest, 9 — best.

Table 8—Influence of condiments on acceptability of patties, evaluated by a 13-member panel[a]

	Flavor	Appearance	Aroma	Juiciness	Tenderness	Overall acceptability
Without condiments	4.3b	5.3a	5.0b	4.9a	4.7b	4.2b
With condiments	5.0a	5.1a	5.4a	4.4b	5.3a	4.8a

[a] Valuas with a column followed by tha sama lattar or lattars wera not significantly diffarant ($P < 0.05$) according to analysis of variance and Duncan's Multipla Ranga Test (1955). Each valua was based on 520 avaluations. Scores were based on a 9-point hedonic scala, 1 – poorest, 9 – best.

Table 9—Soy protein composition[a]

Soy product	Particle size (mm)	Moisture (%)	Ash[b] (%)	Crude fiber[b] (%)	Fat[b] (%)	Protein[b] (%)
Textured						
A	4.76	5.84 ± 0.01	6.96 ± 0.05	3.09 ± 0.13	0.61 ± 0.025	57.16 ± 0.26
B	6.35	8.13 ± 0.09	6.37 ± 0.02	2.72 ± 0.01	0.92 ± 0.002	53.85 ± 0.42
C	12.70	8.43 ± 0.01	6.23 ± 0.13	3.55 ± 0.09	0.49 ± 0.006	54.49 ± 0.39
D	12.70	7.46 ± 0.08	6.97 ± 0.05	4.49 ± 0.38	0.24 ± 0.020	56.36 ± 0.38
Concentrates						
E	1.57	7.08 ± 0.01	6.31 ± 0.05	6.65 ± 0.31	0.27 ± 0.009	70.06 ± 0.41
F	2.37	6.68 ± 0.02	4.04 ± 0.04	6.20 ± 0.08	0.35 ± 0.003	69.14 ± 0.48

[a] Mean and standard error of duplicate samplas
[b] Calculated on a moistura free basis

after fat extraction in the fabrication of soy protein and may be a major factor in differences in fat stability between products. Furthermore, variations in manufacturing procedures might affect the stability of the natural lecithin present in the soy product. Stevens et al. (1970) suggested that in soybeans, lipoxygenase catalyzes oxidation, by molecular oxygen, of cis-methylene interrupted unsaturated fatty acids and their esters to respective hydroperoxides. Maga and Johnson (1972) reported 40% less polyunsaturated fatty acids in soybean milk prepared by cold, than by hot extraction procedures. Fujimaki and co-workers (1966) stated that the following chemical and physical factors can accelerate lipid degradation in soy protein during fabrication: decomposition of natural antioxidants; content of metal catalysts; increased surface area, atmospheric oxygen, and humidity. Sessa et al. (1969) concluded that some lipid degradation occurred in the preparation of defatted flakes and, more importantly, that characteristic soybean off-flavors were closely associated with certain lipids and their decomposition products. Bowers and Engler (1975) also reported some antioxidant effects of soy.

Peroxide value. Peroxide values of the patties are shown in Table 12. Over all months the highest peroxide value was 11.79 meq/kg sample (F-30%), while the lowest was 0.844 (D-30%). Peroxide content was greatest in all-beef patties and F-30% as in the TBA analysis. The correlation between overall TBA and peroxide values was $R = 0.46$ and a coefficient of determination of $r^2 = 0.21$, indicating a rather poor relationship between the two procedures.

Recently, use of tests for peroxides has been limited due to the strictly empirical nature of the methodology. Furthermore, the literature reports that although peroxide number may indicate lipid quality in early stages of deterioration; it becomes less reliable as oxidation proceeds because of degradation of peroxides into many secondary products, including aldehydes, ketones, alcohols and hydrocarbons. The glyceride structure of the lipid also affects the peroxide value during oxidation. Triglycerides, such as those found in soybeans, contain large quantities of polyunsaturated fatty acids (linoleic and linolenic) and have high initial peroxide contents. In our tests the color change during titrations was not distinct, making determinations rather difficult. Although this information certainly places considerable doubt on the data as being an actual representation of peroxide content and extent of lipid oxidation, it was noted that the higher values for peroxide were obtained on all-beef and F-30% patties as was the case for the TBA test. Rackis et al. (1972) reported the presence of peroxidases in maturing soybeans, but these have not been investigated in relation to their effect on soy protein products.

Table 10—Composition of patties[a]

Product	Ash (%)	Fat (%)	Moisture (%)	Protein (%)	pH
		20% level			
Textured					
A	1.21c	21.09def	56.04gh	17.98a	6.11e
B	1.17d	19.36h	58.25c	17.61ab	6.11e
C	1.11e	22.39bc	56.44fg	17.33bc	6.07f
D	1.07f	21.47def	56.87ef	17.25bc	6.10ef
Concentrates					
E	0.98g	23.41a	57.38de	16.90cd	6.15d
F	0.86h	20.48g	60.04b	17.42bc	5.61h
		30% level			
Textured					
A	1.39a	21.45ef	55.51hi	17.52ab	6.23ab
B	1.27b	21.98cd	54.77j	17.40bc	6.25a
C	1.23c	22.83b	55.19ij	16.70d	6.21bc
D	1.28b	21.67de	55.73hi	17.54ab	6.18cd
Concentrates					
E	1.04f	22.19bc	57.52d	17.40bc	6.24ab
F	0.89h	18.37i	61.41e	17.65ab	5.52i
All-beef	0.88h	20.98f	59.57b	18.05a	5.88g

[a] Values within a column followed by the sama letter or letters were not significantly diffarant ($P < 0.05$) according to the analysis of varianca and Duncan's Multiple Range Test (1955).

Table 11—Concentration of malonaldehyde as determined by thiobarbituric acid test[a] in patties during −17°C storage

Product	Months storage[b] 0	3	6	9	12
	20% level				
Textured					
A	0.78ef	1.42fg	1.92def	2.25de	3.31b
B	0.71ef	1.02gh	1.40f	1.46g	2.93bc
C	1.22cde	1.60ef	2.26de	1.84f	2.85bcd
D	0.93def	1.88cdef	1.96def	2.40d	2.42de
Concentrates					
E	1.55bc	2.13cd	2.38d	2.00ef	2.14ef
F	1.54bc	2.28c	3.39c	5.00b	5.04a
	30% level				
Textured					
A	0.76ef	1.44fg	1.72ef	1.69fg	2.52cde
B	0.47f	0.61h	0.73g	0.90h	1.43g
C	1.09cde	1.48fg	1.59f	1.72fg	1.91f
D	1.39cd	2.05cde	2.47d	2.38d	2.81cd
Concentrates					
E	1.08cde	1.68def	1.99def	1.94f	2.24ef
F	2.03b	2.73b	4.15b	4.40c	5.13a
All-beef	4.03a	4.07a	5.47a	5.39a	4.84a

[a] mg/kg sample
[b] Values within a column followed by the same letter or letters were not significantly different ($P < 0.05$) according to analysis of variance and Duncan's Multiple Range Test (1955).

Table 12—Peroxide values[a] of patties during −17°C storage

Product	Months storage[b] 0	3	6	9	12
	20% level				
Textured					
A	2.73b	1.05c	2.17cde	1.62d	4.06cd
B	2.49b	1.04c	1.66e	1.52d	2.22de
C	2.10b	2.64a	2.60cd	3.14a	3.37cde
D	2.02b	0.86c	1.79de	1.45d	4.38c
Concentrates					
E	2.51b	1.06c	1.75e	1.86bcd	2.04e
F	2.39b	2.31a	5.33b	2.78a	8.66b
	30% level				
Textured					
A	2.11b	1.33bc	2.71c	1.58d	2.31de
B	2.53b	1.32bc	1.81de	2.21b	2.34de
C	2.41b	2.68a	2.23cde	1.71cd	2.20de
D	2.55b	0.84c	2.14cde	1.53d	2.45de
Concentrates					
E	2.79b	1.64b	1.57e	2.07bc	3.56cde
F	4.36a	2.63a	7.88a	2.96a	11.79a
All-beef	2.05b	1.80b	4.88b	2.06bc	7.32b

[a] Meq peroxide/kg sample
[b] Values within a column followed by the same letter or letters were not significantly different ($P < 0.05$) according to analysis of variance and Duncan's Multiple Range Test (1955).

Effect of box location on variables studied

Average values for ash, fat, moisture, protein, pH, TBA and peroxide value of samples taken from the tops and bottoms of boxes, for all months of storage were determined. Only the 6-month values showed any significant difference (moisture, TBA) between box location. However, combined analyses over all months indicated samples from the top had significantly less moisture content and significantly higher TBA and peroxide values when compared to corresponding patties from the bottom of the boxes. The magnitude of these differences, however, was too small to be of consequence.

CONCLUSIONS

A CONSUMER PANEL did differentiate between patties containing textured soy protein or concentrate when compared to all meat patties. Patties containing 20% textured soy protein were rated about equal to all-beef patties. Patties containing soy concentrate at either 20% or 30% or patties with textured soy protein at 30% were less desirable than the all-beef patties. Brand differences were evident among the textured soy protein and also between the soy concentrate. When patties containing soy were served to a panel with condiments, acceptability increased. Thus, some brands of textured soy protein can be added at the 20% level as an adjunct to ground meat without detection or adverse reaction by consumers.

The development of rancidity during 12-month storage at 0°C, as measured by the TBA test, was less for patties containing soy protein than for the all-beef patties. The Armed Forces and others requiring a 9-month frozen shelf life can thus take advantage of the benefit of adding soy protein to beef patties without experiencing an inordinate rate of rancidity development.

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Mention of product names throughout this report does not imply endorsement by the U.S. Government.

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USE OF MECHANICALLY DEBONED MEAT IN GROUND BEEF PATTIES

ABSTRACT

Palatability of cooked patties from seven formulations of ground beef patties containing 0 – 30% of added mechanically deboned beef was characterized. Frozen patties were broiled 9 min on an electric grill at 230°C to a "medium" degree of doneness and served to a 7-member trained panel. Mean panel ratings for overall acceptability were greater for patties containing 5, 10, 15 and 20% MDB than for the control (0% MDB). Patties containing 25 and 30% MDB had significantly lower flavor and acceptability ratings than control. As the percentages of added MDB increased, panel ratings for tenderness and juiciness increased. The amount of detectable connective tissue decreased significantly as the percentage of added MDB increased.

INTRODUCTION

THE USDA MPI Bull. 865 (USDA, 1974), providing for the preparation, labeling and distribution of mechanically deboned red meat, has provided means for the possible use of large amounts of protein previously not recovered as a food-grade product. It is estimated that 737 million pounds of beef, 374 million pounds of pork and 19 million pounds of lamb and mutton could become available for human consumption each year by use of this process (Pietraszek, 1975). The technology of production and the characterization of mechanically deboned meats have been studied by Field et al. (1974a, b, c); Field and Riley (1974) and Field (1974). Mechanically deboned meats may be produced from whole carcasses or from the partially cleaned bones from a hand boning operation.

A recent proposal by the U.S. Department of Agriculture (USDA, 1976) stipulated certain requirements for the use of mechanically deboned meat. This proposal would not allow mechanically deboned meat to be used in ground beef, chopped beef or hamburger but would allow it in beef patties. The feasibility of using mechanically deboned meat in ground beef patties has not been studied in detail. The effects of mechanically deboned meat on the sensory properties, storage stability, and composition of ground beef patties have not been documented. The objective of this study was to evaluate the effects of various levels of mechanically deboned meat on palatability and cooking properties of ground beef patties.

EXPERIMENTAL

Meat formulations

The seven formulations of ground beef that were tested are defined in Table 1. Raw meat materials were obtained from U.S. Utility triangles (chuck, foreshank, brisket and plate) and U.S. Choice plates that were fabricated for the AA USDA school lunch program under the supervision of a USDA meat grader (USDA, 1973). Coarse ground samples were randomly selected throughout the daily production (150,000 lb) until a sufficient quantity for the formulations was obtained.

All hand boned meat was ground through a 1.90 cm plate with a Weiler grinder. Mechanically deboned beef (MDB) was obtained from a mixture of necks, backs, ribs and pelvic girdle of U.S. Utility grade beef carcasses that had been manually boned. These bones were passed through a bone cutter into a model AU 4171 Beehive boning machine equipped with a cylinder having 0.46 mm diameter holes. Deboned meat was boxed, quick frozen and stored at −34°C for subsequent analysis and product formulation. Prior to formulation, the frozen MDB was ground through a 1.90 cm plate with a Weiler grinder and stored at −30°C.

For each formulation, appropriate amounts of coarse ground beef and MDB were mixed for 3 – 4 min in a Chemetron mixer. During mixing, CO_2 snow was injected twice in order to maintain an internal temperature of 7°C or less. Following mixing, three random samples were taken for fat analysis with the Hobart fat testing apparatus. Additional fat or lean from U.S. Choice plates was mixed into the formulation to adjust the fat content to about 23%.

The individual batches were ground through a 0.32 cm plate with a Weiler grinder. One hundred patties (114g in weight and 0.95 cm thick) per formulation were formed with a Hollymatic Model 500 patty machine. During processing the product's internal temperature did not exceed 7°C. The remaining product from each treatment was stuffed into 0.90 kg "Keeper Casings" via a VeMag Pump (Model 43). The 0.90 kg packages and patties were boxed separately and placed in a −45°C blast freezer for 48 hr and subsequently stored at −30°C until shipment from Miami, FL to Beltsville, MD.

Chemical analysis

The MDB and five patties from each formulation were analyzed for calcium by atomic absorption spectrophotometry as outlined by Perkin-Elmer Corp. (1964). Essential amino acids were determined, as percent of total protein (except hydroxyproline, tryptophan and hydroxylysine) by use of the Beckman Modified 121 Amino Acid Analyzer. Protein efficiency ratio (PER) was calculated according to procedures outlined by Alsmeyer et al. (1974). Patties for uncooked fat and moisture analysis were frozen in liquid nitrogen and powdered in a high speed blender. Moisture was determined as the mean weight loss of duplicate 3g samples after drying for 24 hr at 102°C. Fat content was determined as the weight loss of the dried samples after extraction for 16 hr in a Soxhlet apparatus with 35 ml of diethyl ether. The heaters were adjusted to allow 3 – 4 drops of ether per second to drip through the sample.

Objective evaluations

Frozen patties were broiled 9 min (4.5 min on each side) on an electric grill (approximately 275°C) to a "medium" degree of doneness. Ten patties from each formulation were randomly selected, cooked, and weighed immediately after cooking to determine weight loss during cooking. Values are reported as loss from the frozen to the cooked state. Degree of doneness was scored by a two-member panel with the use of an 8-point standardized photographic scale 5 min after sectioning. The same ten patties were evaluated with the Instron Universal Testing Instrument for maximum shear force by use of the single blade technique as described by Cross et al. (1976a).

Table 1 — Proportion of mechanically deboned beef (MDB) in the ground beef formulation

% MDB	Beef[a] kg	MDB kg	Total[b] kg
0	184.0	0	184.0
5	87.4	4.4	91.8
10	165.6	16.6	182.2
15	78.2	11.8	90.0
20	147.2	29.4	176.6
25	69.0	17.3	86.3
30	128.8	38.6	167.4

[a] Beef source: US Utility triangles and Choice plates.
[b] Larger portions were formulated for every other treatment for use in storage studies.

[1] Livestock Division, AMS, USDA, Washington, DC 20250
[2] Texas Agricultural Experiment Station, Texas A & M University, College Station, TX 77843
[3] Statistical Services, AMS, USDA, Washington, DC 20250

Table 2 — Composition o unc ooked ground beef patties containing mechanically deboned bee f

Formulation	Moisture %	Fat wet) %	Protein %	Ca %	PER[a]	Ess. amino acids[b]
Control,						
0% MDB	58.47	25 28	16.24	0.01	2.52	38.46
5% MDB	38.79	25 09	16.06	0.06	2.96	40.84
10% MDB	57.08	26 90	15.93	0.09	2.83	38.73
15% MDB	60.23	23 09	16.59	0.09	3.68	38.05
20% MDB	63.53	20 26	16.09	0.12	2.88	40.79
25% MDB	61.51	22 41	15.92	0.16	3.14	45.44
30% MDB	60.65	23 93	15.23	0.19	3.14	37.98
100% MDB	64.96	18 31	15.68	0.74	3.13	42.02

[a] PER (protein Efficiency Rati) calculated according to procedures outlined by Alsmeyer et al. (1974).
[b] As a percentage of total prote n

Table 3 — Mean values for cooking loss, degree of doneness and shear force

Treatment	Total cooking loss %	Degree of Doneness[a]	Max shear force Newtons
Control, 0% MDB	38.6[b]*	3.0 [d]	66.68[b]
5% MBD	35.1[c]	4.9 [c]	67.66[bc]
10% MDB	36.1[c]	5.3 [bc]	59.82[c]
15% MDB	35.2[c]	5.9 [bc]	57.86[c]
20% MDB	39.6[b]	5.4 [bc]	56.88[c]
25% MDB	36.1[c]	6.2 [b]	46.09[d]
30% MDB	38.3[b]	5.9 [bc]	45.11[d]

[a] Evaluated with color photos with 1 = very well done; 4 = medium and 8 = very rare.
[bcd] Mean values in the same column bearing a common superscript do not differ significantly ($P > 0.05$).
* No linear or quadratic effects found to be significant

Trained sensory panel evalu tion

Male and female panelist wer selected from the scientific and ancillary staff of the Agricultur l Re earch Center. Selection was based on assessments of repeatability of s ores on duplicate samples and consistency of ratings in relation o th group. Training was conducted over a period of 3 wk and data f om t e training sessions provided information for selection of a 7-memb r panel. After each training session, discussions were held with he p nelists in order to achieve unanimity in the interpretation of the scori g system. Panelists evaluated the hot samples (approx 20 – 25g) in b oths equipped with MacBeth "North Sky Daylight" lighting. Th trai ed 7-member panel rated each patty for tenderness and juicines on n 8-point rating scale (8 = extremely tender or juicy and 1 = ext eme y tough or dry). The amount of connective tissue residue remai ing t the end of mastication was rated on an 8-point scale (8 = none and = abundant amount). The panel was trained to evaluate tendern ss, j iciness and amount of connective tissue. The panel was also aske to ubjectively rate the samples for desirability of appearance, arom , fl vor and for overall desirability (8 = extremely desirable and 1 = ex remely undesirable). The taste panel evaluation was conducted o er a time span of 4 wk with a total of 14 sessions with four samples er s ssion. Each of the four samples were sampled individually and t e or er of presentation randomized. Each treatment (Table 1) was rep ated ight times over the 14 sessions.

Consumer panel evaluation

Fifty patties from each orm lation were shipped by air freight to meat scientists at Texas A & M Jniversity for consumer panel evaluation. Frozen patties were b oile 14 min (7 min on each side) on an electric grill to a "medium" deg ee of doneness. Cooking times varied for patties prepared at the two l cations because the grills used at the Texas A & M laboratory we e wr pped with foil to control the flow of air during cooking. Thus, th co king time required to reach the same degree of doneness was long r. D ring the course of 1 wk, 77 consumer panelists (age range 19 – 5 ; 68 males and 9 females) were asked to evaluate ground beef patti s fo mulated with different amounts of mechanically deboned beef. Eac panelist was asked to evaluate samples from four of the seven reatr ents using an incomplete latin square design. Panelists were famili rize with the taste panel forms, but were not told the composition o the eef patties. Each panelist scored the sample for appearance, flav r, te ture, juiciness and overall desirability on a like/dislike scale, with = l ke extremely and 1 = dislike extremely. The panelists were also aske to classify the texture and flavor as acceptable or unacceptable and to check one or more blanks corresponding to any off-texture r fla or.

Statistical analysis

Data were reduced by an lysis of variance as outlined by Steel and Torrie (1960). When treatm nts (ercent deboned meat) were found to be significant, the relationsh p be ween percent deboned meat and the trained sensory response wa stu ied by fitting a response function to the data rather than using mean s paration. When treatments are equally spaced values of a theore icall continuous variable such as percent deboned meat, the single c mpa isons given by mean separation may not give the most informati n ab ut the problem being studied. In this study the more important t sk w s to find if there were possibly some continuous relationship between percent of deboned meat and palatability – perhaps to be approximated by a polynomial function. If a relationship exists, the order of the polynomial which approximates it needs to be determined. These questions are not addressed using any classical mean separation techniques, but rather are addressed using single degree of freedom contrasts or orthogonal polynomials in the analysis of variance. Since, in this study, percent deboned meat is a continuous variable, the more approximate question of a functional relationship between percent deboned meat and palatability characteristic was investigated. Polynomials of appropriate order are reported.

RESULTS & DISCUSSION

RESULTS OF COMPOSITION of uncooked ground beef patties containing different levels of mechanically deboned beef (MDB) are presented in Table 2. As expected, moisture content increased as fat content decreased. Percent calcium increased with level of MDB in the formulation. The 100% MDB sample contained 0.74% calcium which is within the level in the USDA proposed regulations (USDA, 1976). The maximum percentage of calcium in the ground beef mixtures was 0.19% in the 30% MDB formulation. PER and percentage of essential amino acids exceeded the proposed USDA requirements (USDA, 1976) in all formulations. The addition of MDB to ground beef enhanced the nutritional quality of the product by increasing the levels of calcium, PER and essential amino acids. Forbes et al. (1921), Mitchell et al. (1937) and Walker (1972) reported that calcium from bone is readily absorbed. The additional calcium in MDB may be nutritionally beneficial since many of the 138 articles reviewed by Walker (1972) point to calcium deficiencies in the human diet.

Mean values for cooking loss, degree of doneness and Instron shear force are presented in Table 3. Levels of MDB and cooking losses were not consistently associated. The formulation with the highest moisture content (20% MDB, Table 2) also sustained the highest cooking loss; although the cooking loss was not significantly different from the control formulation. Degree of doneness ratings increased (less well done) with level of MDB. Apparently cooking times might require slight adjustments if MDB were added. Maximum force required to shear a beef patty decreased significantly with increased levels of MDB. However, the formulation with 5% added MDB was not significantly different in shear force from the control formulation.

Tenderness and juiciness increased and amount of connective tissue (subjectively evaluated by panel) decreased with increased amounts of MDB (Table 4). The control formulation was made up of Utility triangles and Choice plates. Cross et al. (1976b) reported that ground beef prepared from U.S. Utility or lower grade beef was unacceptably tough and high in de-

Table 4 — Trained descriptive panel palatability ratings of ground beef patties containing mechanically deboned beef.

Treatment	Tenderness[e]	Juiciness[b]	Connective[c] tissue	Appearance[d]*	Aroma[d]*	Flavor[d]	Overall[d]
Control, 0% MDB	5.2	5.9	4.7	6.0	6.0	6.1	5.6
5% MDB	5.7	5.9	5.3	6.2	6.0	6.2	6.0
10% MDB	5.7	6.1	5.4	6.1	5.8	6.0	5.8
15% MDB	5.9	6.2	5.5	6.1	5.8	5.8	5.7
20% MDB	6.1	6.2	5.8	6.1	6.0	5.6	5.7
25% MDB	6.5	6.3	6.0	6.3	5.8	5.0	5.2
30% MDB	6.7	6.5	6.3	6.2	5.9	4.9	5.0

[e] Tenderness: 8 = extremely tender and 1 = extremely tough.
[b] Juiciness: 8 = extremely juicy and 1 = extremely dry.
[c] Connective tissue: 8 = none and 1 = abundant
[d] Appearance, aroma, flavor and overall: 8 = extremely desirable and 1 = extremely undesirable.
* No significant linear or quadratic effects or pairwise differences found among means

tectable connective tissue. In the present study, MDB apparently minimized the undesirable textural properties of Utility grade gound beef. The mechanism is unknown, but possibly MDB diluted the strands of connective tissue in the formulation so that its detection was minimized. Field et al. (1974a, b, c) and Field et al. (1976) reported that mechanically deboned meat is always lower in connective tissue than hand boned meat because some tendon is discarded with the bone.

Appearance and aroma ratings were not affected significantly ($P < 0.05$) by addition of MDB in the formulation (Table 4). The appearance ratings increased slightly as the level of MDB increased, probably because of the darker brown surface and the "medium rare" degree of doneness.

Flavor seems to be the limiting factor in adding MDB to ground beef (Table 4). Except for the 5% MDB formulation, flavor ratings decreased with added MDB. The decrease was greatest between the 20 and 25% levels. A sensory parameter rating of 5.0 or above is usually considered "acceptable," while 4.9 and below is considered "unacceptable." These are somewhat arbitrary designations and therefore should not be applied rigidly. Apparently MDB can be added at least to the 15 or 20% level without approaching this 5.0/4.9 cutoff. Ratings for overall acceptability were usually closely aligned with the one or two limiting (or lowest) palatability traits.

The means in Table 4 suggested that the seven sensory parameters were strongly related to the percent MDB. Therefore, as previously discussed in the experimental section, rather than perform mean separation on the data in Table 4, a polynomial in terms of percent MDB was fit to the means for selected taste panel traits and was corrected for other effects in the study (Table 5).

The functions show that ratings for tenderness, juiciness and amount of connective tissue increased linearly with percent MDB. For overall acceptability, the response initially increased then decreased as MDB increased. The maximum estimated response for overall acceptability (5.87) occurred at the 7.4% MDB level. The function for flavor has the same form as that for overall; however, the estimated maximum response was at 0.1% MDB which indicates essentially that flavor decreased as MDB increased.

Consumer panel evaluations

All means for consumer palatability ratings were above 5.0 (Table 6), and did not differ significantly among formulations for appearance, flavor and overall acceptability. Trends are similar for the trained (Table 4) and the consumer panels (Table 6); texture or tenderness and juiciness tended to increase with added MDB. The failure of the consumer panel to detect significant differences between the control patties and patties with MDB might be explained by the fact that the consumer panel sampled the products from each treatment only once, while the trained panel sampled each product eight times. Possibly the consumer panel would have begun to detect differences with prolonged testing or training. The trained panelists were selected on the basis of their ability to detect differences in the test attributes and probably were more sensitive to differences than the untrained consumers.

Table 5 — Regression analyses of palatability traits and level of added mechanically deboned beef

Function[a]	R^2
Tenderness = $5.27 + 0.046X^b$	0.96
Juiciness = $5.85 + 0.21X^b$	0.96
Connective tissue amount = $4.84 + 0.048X^b$	0.96
Flavor = $6.14 + 0.0003X^b - 0.0015X^{2b}$	0.97
Overall = $5.76 + 0.029X^b - 0.002X^{2b}$	0.95

[a] Functions developed on means from trained sensory panel
[b] X = percent added mechanically deboned beef.

Table 6 — Consumer ratings for ground beef patties containing mechanically deboned beef

Formulation	Appearance[a]	Flavor[a]	Texture[a]	Juiciness[b]	Overall[a]
Control					
0% MDB	6.0[c]	6.0[c]	5.1[e]	5.6[cde]	5.8[c]
5% MDB	5.7[c]	5.8[c]	5.7[cd]	5.4[e]	5.6[c]
10% MDB	6.0[c]	5.7[c]	5.8[cd]	5.6[cd]	5.8[c]
15% MDB	5.8[c]	5.6[c]	5.7[cd]	5.8[cd]	5.6[c]
20% MDB	5.9[c]	5.7[c]	5.7[cd]	5.7[cde]	5.5[c]
25% MDB	6.0[c]	6.0[c]	6.0[c]	5.8[c]	5.9[c]
30% MDB	5.4[c]	5.5[c]	5.4[de]	6.0[c]	5.4[c]

[a] Mean values based on 8-point hedonic scales (8 = like extremely; 1 = dislike extremely).
[b] Means based on 8-point descriptive scale (8 = extremely juicy; 1 = extremely dry).
[cde] Mean values in the same column bearing different superscripts differ significantly ($P < 0.05$). n = 77 panelists.

The consumer panel also rated texture and flavor as either "acceptable" or "unacceptable" (Tables 7 and 8). Each panelist was asked to classify the texture or flavor of the "unacceptable" patties by checking one or more blanks corresponding to any off flavor or texture. Except for the 25 and 30% levels, the percent rated as "unacceptable" in texture (Table 7) decreased with added MDB. More than 60% of the panelists rated the control patties as "unacceptable" in texture. The predominant defect was described as "too tough or rubbery" followed

Table 7 — Consumer panel responses for textural acceptability and descriptions of defects in unacceptable patties

	Textural acceptability[a]		Description of defects in unacceptable patties[b]						
Formulation	Acceptable	Unacceptable	Too mushy	Too fine	Too coarse	Too tough or rubbery	Gritty	Too crumbly	Other
Control, 0% MDB	37.5	62.7	3.8	1.3	12.5	38.8	2.5	2.5	1.3
5% MDB	48.8	51.2	3.8	3.8	16.3	25.0	2.5	0	0
10% MDB	54.4	45.5	5.1	2.5	11.4	17.7	7.6	1.3	0
15% MDB	56.9	43.1	17.7	6.3	8.9	6.3	1.3	1.3	1.3
20% MDB	56.6	43.4	16.9	9.6	7.2	2.4	3.6	2.4	1.2
25% MDB	52.9		12.9	9.4	5.9	11.8	3.5	3.5	0
30% MDB	45.7	54.3	22.2	11.1	4.9	7.4	8.6	0	0

[a] Numerical values are percentages of all responses.
[b] Numerical values are percentages of responses assigned by panelists who considered the texture unacceptable. n = 77 panelists.

Table 8 — Consumer panel responses for flavor acceptability and descriptions of defects in unacceptable patties

	Flavor acceptability[a]		Description of defects in unacceptable patties[b]						
Formulation	Acceptable	Unacceptable	Musty	Medicinal	Rancid	Salty	Bitter	Yeasty	Other
Control, 0% MDB	84.4	15.6	6.5	0.0	1.3	1.3	0.0	2.6	3.9
5% MDB	72.7	27.3	9.1	5.2	0.0	1.3	3.9	1.3	6.5
10% MDB	74.4	25.6	17.9	2.6	0.0	0.0	1.3	1.3	2.6
15% MDB	61.5	38.5	11.5	6.4	3.8	5.1	0.0	0.0	11.5
20% MDB	62.5	37.5	12.5	2.5	3.8	1.3	3.8	5.0	8.8
25% MDB	71.6	28.4	13.6	2.5	1.2	1.2	2.5	2.5	4.9
30% MDB	60.8	39.2	12.7	7.6	3.8	1.3	3.8	12.7	8.9

[a] Numerical values are percentages of responses.
[b] Numerical values are percentages of responses assigned by panelists who considered the flavor unacceptable. n = 77 panelists.

y "too coarse." Consumer panelists rated patties with high evels of MDB as being "too mushy" or "too fine." Apparently he addition of MDB at levels up to 15 or 20% tended to offset he undesirable textural characteristics of the control beef patties.

The percentage of patties rated as "unacceptable" in flavor ncreased with the higher levels of MDB (Table 8). More than 0% of the panelists rated patties as "acceptable" in flavor. Apparently, the flavor of patties was acceptable to more panelsts than was the texture (Table 7). The predominant defect in ll treatment groups was described as "musty." Further research, with a trained flavor profile panel, should be conducted o identify the intensity and order of appearance of the flavor omponents.

It was concluded, from the palatability and cooking loss ata, that MDB can be added to ground beef at levels up to 15 r 20%. The textural properties of the cooked beef patty were mproved by the addition of MDB. These conclusions are supported by data from trained and consumer panels. The protein uality of ground beef was enhanced by the addition of MDB s evidenced by increased PER and percent essential amino cids. The increased levels of calcium may also improve the utritional value of the beef patties as explained by Forbes et l. (1921); Mitchell et al. (1937) and Walker (1972). Of the actors studied, undesirable flavor and mushy texture were the nost common objections expressed by panelists about ground eef patties that contained high levels of MDB. Flavor of MDB hould be monitored during prolonged storage at different emperatures to further define possible limitations on the use f MDB in gound beef patty formulations.

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EFFECT OF DESINEWING VERSUS GRINDING ON TEXTURAL PROPERTIES OF BEEF

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ABSTRACT

The objective of this study was to evaluate the effect of mechanical desinewing (a new process whereby the major portion of the sinew or connective tissue and foreign particles is removed) vs grinding on textural properties of comminuted beef. Desinewing generally improved textural properties of beef patties with greatest effects on meat from mature animals. The 0.19 cm desinewing head was superior to 0.25 or 0.32, but further research is needed to refine head selection.

INTRODUCTION

IN THE UNITED STATES the consumption of ground beef has increased steadily over the past decade. Cross et al. (1976a, 1977) reported that connective tissue was and is a major problem associated with the acceptance of ground beef. They found that meat from U.S. Utility or lower quality or from minor cuts of any grade, produced a ground product that was unacceptably high in connective tissue. Cross et al. (1976b) reported that method of grinding affected textural properties of ground beef, especially the amount of connective tissue remaining in the cooked product. These results indicated that the size of the plates in the initial grind were directly related to the amount of connective tissue in the cooked product. The major sources of lean for ground beef are minor cut trimmings from young cattle and major cuts from older, lower quality cattle. Since it is not economically feasible for the industry to alter its source of lean, we are investigating methods of comminution that would remove a portion of the objectionable connective tissue.

A new process has been developed whereby the major portion of the sinew or connective tissue and foreign particles can be removed. The process is called "desinewing" and the device is an adaptation of the Beehive mechanical deboning machine. Gillett and Tanatikarnjathep (1976) reported that mechanical desinewing removed about half of the connective tissue from beef shanks and plates. The objective of this study was to evaluate the effect of desinewing versus grinding on textural properties of comminuted beef.

EXPERIMENTAL

EIGHTEEN FORMULATIONS of comminuted beef were prepared as outlined in Table 1. All raw materials were selected from the same day's slaughter. The various cuts were removed from each carcass, boned and shipped about 10 miles in a refrigerated truck to the commercial research laboratory. The plates and flanks from the U.S. Choice minor cuts were partially trimmed of fat prior to communition. About 40% of the Choice minor cuts consisted of undefatted foreshank lean and fat. Fat from U.S. Choice plates was added to the bull triangle and U.S. Utility triangle meat to increase the fat content.

For each treatment, a minimum batch of 50 kg was prepared. All raw material was passed through a grinder plate having 5.08 cm diameter holes. Grab samples were collected for fat analysis, and were further comminuted by passing them through a colloid mill. Fat content was determined by the Modified Babcock procedure. Fat content was standardized at 24 ± 2% by the addition of appropriate amounts of fat or lean. Based on previous determinations, the desinewing process was expected to remove 2–3% of the fat; therefore, the fat content for the raw materials to be desinewed was adjusted to about 26%.

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Table 1—Treatment formulations and listing of tables where comparisons are made

Raw beef material[a]	Methods of comminution	Table 2	3	4	5
Choice Minor Cuts (CM)	Grind (G)		X	X	
Choice Minor Cuts	Desinew 1 (D1)	X	X	X	
Choice Minor Cuts	Desinew 2 (D2)	X			
Choice Minor Cuts	Desinew 3 (D3)	X			
Utility Triangles (UT)	Grind		X	X	
Utility Triangles	Desinew 1	X	X	X	
Utility Triangles	Desinew 2	X			
Utility Triangles	Desinew 3	X			
Choice Flanks	Grind		X		
Choice Flanks	Desinew 1		X		
Bull Triangles (BT)	Grind		X		
Bull Triangles	Desinew 1		X		
CM/CM 50/50	G/D			X	
UT/UT 50/50	G/D			X	
CM/UT 50/50	G/G				X
CM/UT 50/50	G/D				X
CM/UT 50/50	D/G				X
CM/UT 50/50	D/G				X

[a] CM = flanks, plates and foreshanks; UT and BT = plates, foreshanks and chucks; G = Three stage grind, 5.08, 1.90 and 0.32 cm plates; D1 = 0.19 cm head; D2 = 0.25 cm head; and D3 = 0.32 cm head

Grinding

Following the initial grind and fat adjustment the meat was mixed for 2 min in a mechanical mixer. Temperature was monitored during the mixing process and if it exceeded 2–3°C, sufficient CO_2 snow was added to bring the internal temperature of the ground product below 3°C. After mixing, the product was ground through a 1.90 cm plate and finally through a 0.32 cm plate.

Desinewing

Meat was passed through a Beehive Desinewing Machine (Model AU 6173). Heads of three different sizes were used and had holes with diameters of 0.19, 0.25 and 0.32 cm. Prior to the desinewing, fat content was adjusted by the addition of fat that had been passed through the 0.19 cm desinewing head. The product was mixed for 2 min and CO_2 snow was added if necessary.

Combinations

Various combinations of raw meat materials (U.S. Choice minor cuts and U.S. Utility triangles) and methods of communition (grind and desinew) were prepared. Desinewed meat (0.19 cm head) was added in equal amounts to ground meat after it had been passed through the 1.90 cm plate. Following a 2-min mix, the product was ground through the 0.32 cm grinder plate. Desinewed Utility triangles and Choice minor cuts were combined in equal amounts and mixed for 2 min but were not ground.

Patties

Communited meat from each treatment was formed into 142g patties with a Hollymatic Patty Machine. Patties were placed in plastic bags, covered with CO_2 snow and placed in a −20°C freezer. After 72 hr, patties were packed in dry ice and shipped via air freight to Beltsville, MD.

Cooking

Patties were broiled from the frozen state on electric Farberware grills (model 450) for 6 min per side. Cooked patties were quartered and served immediately to panelists for sensory evaluation. Degree of

Table 2—Effect of desinewing method on the textural and chemical properties of beef[a]

Desinewing head size[b] (cm)	Tenderness		Panel connective tissue amount		Instron shear force (kg)		Total collagen (mg/g, wet basis)	
	CM	UT	CM	UT	CM	UT	CM	UT
0.19	6.31b	6.61b	6.01b	6.36b	6.64b	6.26b	14.39c	16.61c
0.25	5.70b	5.50b	5.26b	4.40c	6.62b	10.07c	16.00c	27.20b
0.32	5.77b	4.78c	5.51b	3.92c	8.05b	11.18c	25.47b	22.31b

[a] Means in the same column followed by the same letter are not significantly different ($P < 0.10$).
[b] Desinewing methods differed according to diameter of holes in the heads of the machine.

doneness was evaluated, by comparison with color photographs, on all cooked patties 5 min after cooking.

Panel selection and training

A 10-member panel was selected and trained in descriptive attributes by the procedures of Cross et al. (1978). The panel rated the following attributes on an 8-point structured scale: (a) tenderness and juiciness, with 8 = extremely tender and juicy; and 1 = extremely tough and dry; and (b) connective tissue amount with 8 = none and 1 = abundant. Panelists rated five samples at each of 22 sessions. Each treatment was replicated six times and samples to be evaluated in each session were selected via a table of random numbers.

Instron shear

Ten patties from each treatment were broiled for determination of shear values. The cooked patties were cooled for at least 2 hr, and shear force was measured on each quarter of the patty with the single blade shearing device attached to the Instron as described by Cross et al. (1976b). Data were recorded for the maximum force required to shear through the meat patty.

Hydroxyproline

Duplicate samples (4g) of frozen powdered meat from each treatment were heated for 70 min at 77°C in 0.25% strength Ringer's solution and separated into supernatant and residue fractions according to the procedures of Hill (1966). Each fraction was individually hydrolyzed in 6N HCl at 102°C for 16 hr at 1 atm pressure.

The hydroxyproline content was determined as outlined by Bergman and Loxley (1961). Total collagen content (mg/g) was calculated by multiplying the hydroxyproline content of the residue by 7.25 and that of the supernatant by 7.52.

Statistical analysis

The experimental design was structured so that each treatment occurred once in each replication and once in each order (1 to 5). The design was a partially balanced incomplete block design according to Clatworthy (1973). Each observation used in the analysis was the average of the scores of all panelists. Data were subjected to statistical analysis of variance according to Snedecor (1956) and to mean separation by Scheffe's method (1959). Means for the taste panel traits were adjusted for session/replication effects. Means for degree of doneness were evaluated by nonparametric analysis of variance (Kraskal-Wallis procedure) discussed in Hollander and Wolfe (1973).

RESULTS & DISCUSSION

DATA IN TABLE 2 describe the effect of desinewing method on textural and chemical properties of beef. Since interactions between type or grade of meat and method of communition were significant, the data are presented separately for each type and grade of meat. Three desinewing methods (0.19, 0.25 and 0.32 cm hole sizes) were applied to Choice minor cuts (CM) and Utility triangles (UT). No significant differences among methods were evident for CM cuts in either panel or Instron ratings (Table 2). For UT, the methods with the 0.19 and 0.25 cm head sizes were superior in terms of panel ratings of tenderness, and the 0.19 cm head was best for connective tissue amount and Instron shear force.

Degree of doneness, cooking losses, and juiciness were not significantly affected ,by method of desinewing (data no' shown). As the hole size increased from 0.19 to 0.25 and 0.32 cm, the amount of total collagen in the final product increased significantly. With CM or UT, the amount of collagen in the product was significantly less from the 0.19 than the 0.32 cm head. These differences in collagen were also reflected by the differences in the panelists' ratings for tenderness and connective tissue.

Based on the results in Table 2, the desinewing method with the 0.19 cm head was used to prepare meat for comparison with ground meat. Data in Table 3 describe the effect of grinding or desinewing on the textural and chemical properties of beef. The two methods of communition (grinding and desinewing—0.19 cm head) were applied to Choice minor cuts (CM), Utility triangles (UT), Choice flanks (CF) and bull triangles (BT). Bull triangles were from 'C' maturity carcasses and UT from D/E maturity carcasses. Although not all differences were significant, desinewed patties from CM cuts consistently tended to be rated more tender (panel and Instron) and lower in detectable connective tissue than ground patties (Table 4). Patties from desinewed UT and BT cuts were rated significantly more tender (panel) and lower in connective tissue than patties from ground UT and BT. Patties from desinewed BT were also more tender, as indicated by lower Instron values, than patties from ground BT. Desinewed UT patties also had significantly higher juiciness ratings than ground patties (not shown in table).

Apparently, the effect of desinewing was greatest on cuts from older (C-E versus A maturity) carcasses, which usually

Table 3—Effect of grinding or desinewing method[a] on the textural and chemical properties of beef[b]

Type of cut[c]	Tenderness		Panel connective tissue amount		Instron shear force (kg)		Total collagen (mg/g, wet basis)	
	Grind	Desinew	Grind	Desinew	Grind	Desinew	Grind	Desinew
CM	5.61c	6.31c	5.56c	6.01c	7.35c	6.64c	33.52c	14.39d
UT	5.36d	6.61c	4.95d	6.36c	7.49c	6.26c	29.86c	16.61d
CF	5.18c	5.49c	5.90c	5.66c	6.09c	7.72c	10.86c	12.47d
BT	5.08d	6.83c	4.63d	6.97c	8.72c	5.55d	13.80c	7.67d

[a] Grinding = 5.08; 1.90 X 0.32 cm plates and desinewing = 0.19 cm diameter holes.
[b] Paired means in the same row followed by the same letter are not significantly different ($P < 0.10$).
[c] CM = Choice minor cuts; UT = Utility triangles; CF = Choice flanks; BT = bull triangles.

Table 4—Textural and chemical properties of various mixtures of ground and desinewed beef[a]

Percent desinewed beef[b]	Panel tenderness		Instron shear force, kg		Panel connective tissue amount		Total collagen (mg/g, wet basis)	
	CM	UT	CM	UT	CM	UT	CM	UT
0	5.61b	5.36bc	7.35b	7.49bc	5.56b	4.95c	33.52b	29.86b
50	6.08b	4.84c	6.94b	9.94b	6.36b	4.76c	25.96c	29.30b
100	6.31b	6.61b	6.64b	6.26c	6.01b	6.36b	14.39d	16.61c

[a] Means in the same column followed by the same letter are not significantly different ($P < 0.10$).
[b] Desinewed beef was passed through the 0.19 cm head.

have large amounts of tough connective tissue. This is important because mature animals are the major source of beef for hamburger. Cross et al. (1976a, 1977) indicated that ground beef from old animals is unaceptably high in connective tissue. The panel rated patties made from ground BT lowest in quality in terms of tenderness and connective tissue, but rated those from desinewed BT highest for these same traits (Table 3).

The effects of desinewing versus grinding on total cooking loss and degree of doneness were not significant (data not shown). From all cuts except CF, desinewed beef contained significantly less collagen than ground beef. These differences were reflected in the ratings for tenderness and connective tissue (Table 3).

Three mixtures of desinewed and ground beef from two classes of cuts (CM and UT) were prepared as outlined in Table 4. Generally, as the percent desinewed meat of the CM formulation increased, ratings for tenderness increased and Instron shear force decreased. Although these differences were not significant, the trend is similar to that in Table 2. For UT, 100% desinewed beef was the best in terms of tenderness, connective tissue and Instron shear force. It is impossible to explain why UT containing 50% ground/desinewed beef were rated tougher than either of the other formulations. This segment of the experiment will be repeated to determine whether that effect was real. Juiciness, cooking losses, and degree of doneness ratings were not significantly affected by the amount of desinewed beef in the formulation (data not shown). As expected, total collagen decreased as the percentage of desinewed beef increased. The change was greatest between 100% and 50% desinewed.

Various combinations of desinewed and ground cuts were prepared and the results are presented in Table 5. From CM and UT cuts, four 50/50 mixtures in all combinations, were prepared of ground and desinewed meat. The CM ground/UT desinewed and CM desinewed/UT ground treatments were more tender, according to the Instron, than the CM ground/UT ground mixture. Juiciness, total cooking loss, and degree of doneness did not differ significantly among the four mixtures (data not shown). Mixtures containing UT desinewed beef contained significantly less total collagen than other mixtures. In mixtures with ground UT beef, desinewing of CM did not significantly reduce total collagen. Generally, there appears to be few differences in tenderness between mixed ground beef regardless of the desinewing treatment.

CONCLUSIONS

DESINEWING generally improved the textural properties of beef patties. The effects of desinewing were greatest on meat from mature animals that were high in connective tissue. That finding is economically important because most ground beef is now prepared with meat from mature animals or with minor cuts from younger animals. Meat desinewed through the 0.19 cm head was superior to that desinewed through the 0.25 and 0.32 cm heads. Choice of the method of communition probably should be based on the nature of the raw material, but further research is needed to refine the selection of heads.

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Mention of trade names does not imply endorsement by the U.S. Government.

Table 5—Effect of combinations of desinewed and ground cuts on textural and chemical properties of beef[a]

Formulation[b]	Panel tenderness	Instron shear force, kg	Panel connective tissue amount	Total collagen (mg/g, wet basis)
CM ground/UT ground	5.76c	7.95c	5.41c	18.53c
CM ground/UT desinewed	5.32c	5.97d	5.47c	14.08d
CM desinewed/UT ground	5.75c	5.22d	5.76c	18.00c
CM desinewed/UT desinewed	6.07c	6.85cd	5.82c	13.56d

[a] Means in the same column followed by the same letter are not significantly different ($P < 0.10$).
[b] Desinewed beef was passed through the 0.19 cm head. Beef from Choice minor cuts and Utility triangles were combined in equal amounts.

OBJECTIVE MEASUREMENTS OF TEXTURE IN GROUND BEEF PATTIES

H. R. CROSS, MARILYN S. STANFIELD and W. J. FRANKS JR.

ABSTRACT

eef patties were prepared fro1 1 carı asses ranging in quality grade from J.S. Prime to Cutter and forr ulate 1 into 16 grade/cut combinations. 'exture was evaluated for eac 1 san ple with three devices (two shear nd one compression) adaptec to .he Instron Universal Testing Mahine. The single blade shear (3BS) and circle blade shear (CBS) were sed to determine the maximur 1 for 3 required to shear the sample and o measure the area under the curv), i.e., work. The maximum force equired to compress a core to one- 1alf its original thickness also was etermined. In simple correlati 1ns, nachine readings for single blade rea under the curve and for ma cimu 1 single blade shear force were the 1ost highly correlated with tl e su ojective panel evaluation of conective tissue amount (−0.93 ε nd − 0.92) and tenderness (−0.89 and 0.88). Correlations for CBS vere highly significant but had lower oefficients (−0.86, −0.78; −0.32, − 0.76; respectively) than the SBS. egression equations containing singl 3 blade area, circle blade area and ompression force accounted fo· 95.· % of the variability in subjective anel evaluations for amount of conn ctive tissue and when circle blade hear replaced circle blade area, acco ınted for 92.6% of the variability 1 panel ratings for tenderness.

INTRODUCTION

RESEARCH on objective methods of measuring texture is not new development. Lehm 1n (907) described two instruients for testing the tenderne s of meat. Schultz (1957) ummarized the advantage and disadvantages of various 1echanical methods that had been used to measure meat enderness. Voisey (1976) p ovic 3s an excellent review of intruments used for meat ter derr 3ss evaluation. Interest coninues in the development of new devices and the modification f existing devices, for the 1neas 1rement of texture in meat Szczesniak and Torgeson, 1965; Burrill et al., 1962; Sperring t al., 1959; Kelley et al., 1960; Spencer et al., 1962; Smith nd Carpenter, 1973; Segars e al., 1975).

Tenderness is the principal attribute associated with texure in meats as evidenced by con umer preferences for tender 1eats. Of the many mechan cal levices used to simulate or 1easure tenderness or textu e a perceived by the sensory anel, the Warner-Bratzler ir stru nent is probably the most opular (Szczesniak and Torgeson, 1965). That device is imple and inexpensive but ge 1era es data that may not always orrelate highly with senso y tenderness. Szczesniak and 'orgeson (1965) stated "that 41 of 51 research studies estabshed good to highly significa 1t re ationships between Warner-Bratzler shear and sensory tend 3rness with the remaining tudies showing poor to no significant correlations with senory tenderness."

Many researchers have adapted the meat shear principle of he Warner-Bratzler apparatus to use with the Instron Uniersal Testing Machine. Because of its basic design and its apability to record force-distance relationships accurately, the nstron may be used to quantify other parameters of texture ther than maximum shear force.

Few researchers have used instr 1ments to evaluate texture in ground beef. Cross et al. (1976) demonstrated sensory panel differences in texture (tenderness and amount of connective tissue) in ground beef formulated from different U.S. quality grades. We now report a secondary phase of that study. We evaluated three devices that were designed for use on the Instron to objectively measure texture in ground beef patties. The different U.S. quality grades and cut combinations provided ranges of tenderness, juiciness and connective tissue so that we could evaluate any possible relationships between mechanical measurements of texture and the sensory responses of a trained panel. We wanted to determine whether the mechanical devices could accurately evaluate, with respect to human evaluations, the textural characteristics of cooked ground beef patties.

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Table 1—Sample combination designations

Combination no.	Grade/Cut
1	Prime/chuck
2	Choice/chuck
3	Good/chuck
4	Utility/chuck
5	Cutter/chuck
6	Prime/plate
7	Choice/plate
8	Good/plate
9	Utility/plate
10	Cutter/plate
11	Prime/combination[a]
12	Choice/combination
13	Good/combination
14	Utility/combination
15	Cutter/combination
16	Choice and Cutter/combination

[a] Combination consisted of chuck and plate in equal proportions

EXPERIMENTAL

GROUND BEEF SAMPLES were prepared from 16 different grade/cut combinations (Table 1). Carcasses which were selected and fabricated as described by Cross et al. (1976), ranged in quality grade from U.S. Prime through U.S. Cutter to provide variation in texture. Fat content was standardized at 24 ± 2% by the addition of appropriate amounts of fat or lean and was determined with the Modified Babcock procedure. The ground meat was formed into 75-g patties which were 10 cm in diameter and 0.95 cm thick with a Hollymatic Patty Machine. All patties were placed in boxes (4.5 kg to a box), frozen in a blast freezer (−30°C), and shipped from Oklahoma City, OK, to Beltsville, MD, via air freight.

Cooking

Patties were roasted from the frozen state in a 200°C oven for 9 min, quartered, and served as hot as possible to the panelists. Patties were allowed to cool for 60 min after cooking before sampling for shear and compression.

Panel selection and training

Male and female panelists were selected from the scientific and ancillary staff of the Agricultural Research Center, Beltsville, MD. Panelists were selected and trained according to the procedure outlined by Cross et al. (1978). Panelists individually evaluated the samples under red lights in booths.

The trained panel rated each patty for tenderness and juiciness on a

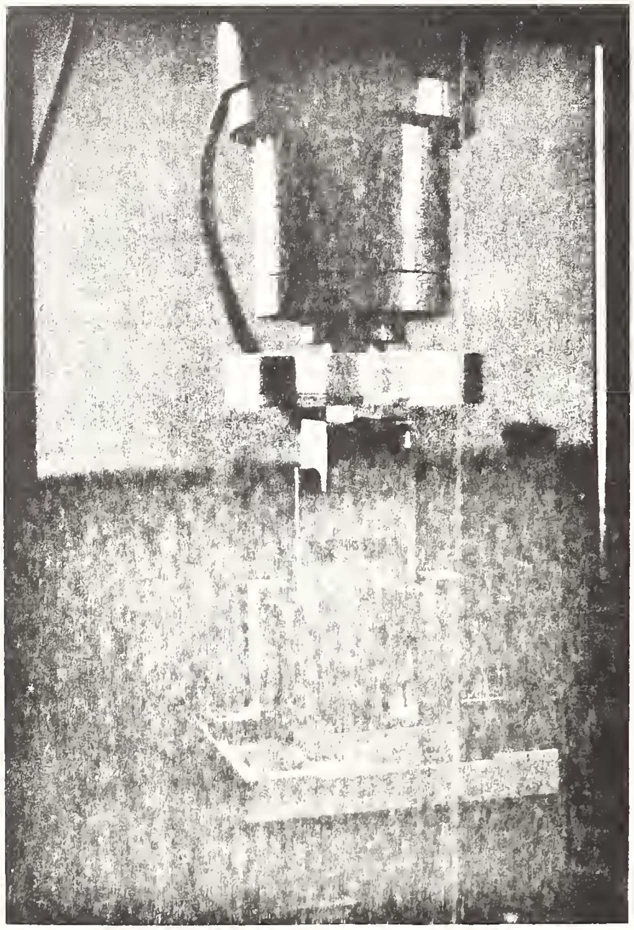

Fig. 1—Single blade shear.

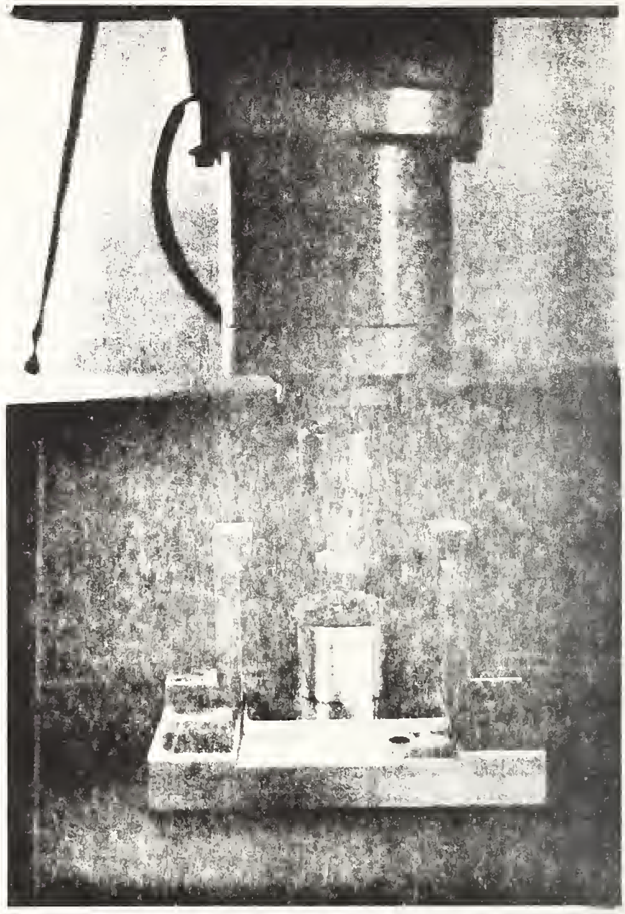

Fig. 2—Circle blade shear.

9-point scale (9 = extremely tender or juicy and 1 = extremely tough or dry). Tenderness and juiciness were evaluated during the first 5–10 chews. The amount of connective tissue residue remaining at the end of mastication was rated on a 9-point scale (9 = none and 1 = very abundant amount). The taste panel evaluations were conducted over eight 3-day periods. Panelists evaluated six ground beef samples each day so that during each 3-day period all 16 grade/cut combinations were tested. In addition, two combinations were repeated once during each 3-day period. If each panelist had been present for every session, there would have been an equal number (9) of evaluations by each panelist on every ground beef combination. In the "ideal" panel situation each combination would have received 144 evaluations, but panelists' attendance was not perfect. Three panelists had fewer than 50 evaluations and averaged 120 evaluations out of a possible 144. To avoid problems in statistical analysis, created by a side disparity in the number of evaluations, we eliminated the data from these three members.

Mechanical measurements

Shear and compressive force tests were carried out with the Instron Universal Testing Machine (type TM). Two shear and one compression devices were adapted to the Instron machine. The rate of crosshead descent for all three tests was 25.54 cm per minute. All test cells were manufactured in-house. The single blade shear (SBS) device used in this study (Fig. 1) consisted of a rectangular dull-edged blade 6.00 cm wide and 0.11 cm thick. There was a 0.04 cm clearance between the shearing edge of the blade and the corresponding edge of the hole in the base plate where the shearing action occurred. Two cooked patties from each grade/cut combination were tested with the SBS. Each patty was cut into four equal sections (3.15 cm square × 0.95 cm thick) to give eight samples per combination (Table 1).

The circle blade shear (CBS) device (Fig. 2) was similar to the slice tenderness evaluator (STE) described by Kulwich et al. (1963) and Segars et al. (1975), except that the CBS device did not have a mechanism to puncture the sample prior to shear. The CBS device consisted of a flat plunger or coin shaped device, 2.52 cm in diameter and 0.72 cm thick, that sheared a sample placed over a cylindrical base. There was 0.01 cm clearance between the shearing edge of the device and the corresponding edge of the hole in the cylinder. Two cooked patties from each grade/cut combination were tested with the CBS. Each patty was cut into three cores (3.81 cm in diameter × 0.95 cm thick) to give six samples per combination (Table 1). Data were recorded for maximum shear force (SBSHEAR and CBSHEAR) and for work or area under the peak curve (SBSAREA and CBSAREA).

The compression device consisted of a flat plate (9.68 cm × 10.16 cm) and a pedestal-like device 7.62 cm in diameter and 0.65 cm thick (Fig. 3). A core (3.81 cm in diameter × 0.95 cm thick) was placed on the plate and the force required to compress the cooked ground beef core to one-half its original thickness was measured. Eight cores were from each of two patties. Ten consecutive "strokes" or "chews," were made on each of the eight cores to give a total of 80 readings for each grade/cut combination (Table 1). Plots (not shown) of compression force (COMFORCE) versus stroke number (1–10) for each core within a combination were obtained. COMFORCE tended to steadily decrease from the first stroke through the tenth, with the rate of decrease becoming less with increasing stroke number. For any given combination, a relatively consistent difference existed between the COMFORCE plots of the eight cores. Examination of these plots indicated that for each stroke the average value of COMFORCE of the eight cores was meaningful in describing the relationships between COMFORCE and stroke number. For purposes of statistical analysis, we chose to average COMFORCE over all cores and strokes for each combination.

The overall average for sensory panel evaluations were used for each grade/cut combination, so there is one observation for each. The average for each combination was the best estimate of the "true" panel response. In this study, our primary interest was that "true," yet unknown, response. The rationale was similar for the use of the average machine reading to represent each combination.

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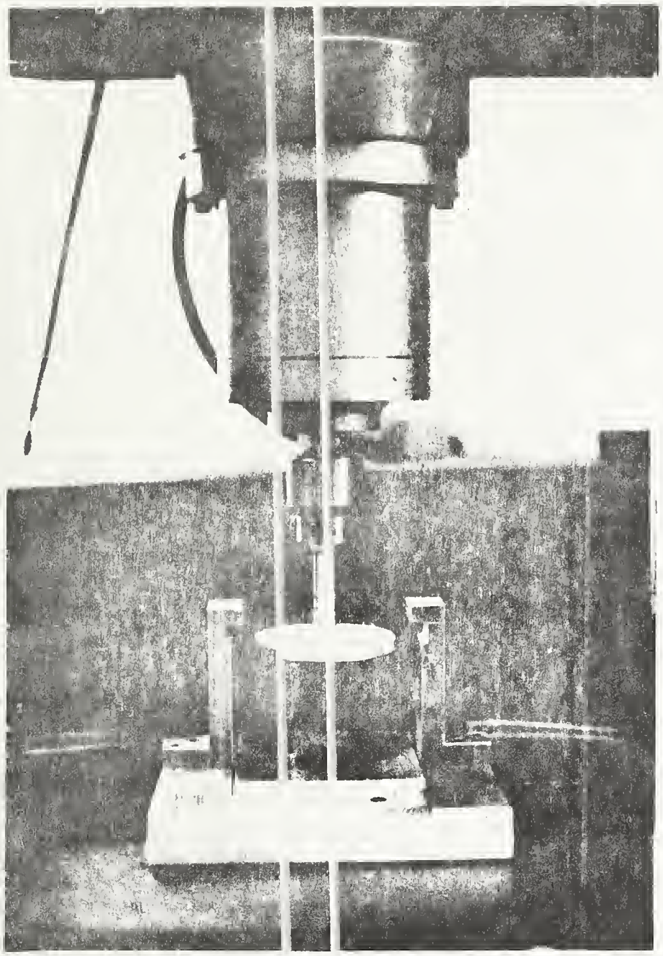

Fig. 3—Com ɔressı ɔn device.

Table 2—Simple correletion coefficients of the Instron readings and peletebility cheracteristics

Instron	Palatability characteristics Tenderness	Juiciness	Connective tissue
SBSHEAR[a]	−0.88**	−0.58*	−0.92**
SBSAREA[a]	−0.89**	−0.52*	−0.93**
CBSHEAR[a]	−0.76**	−0.56*	−0.78**
CBSAREA[a]	−0.82**	−0.47	−0.86**
COMFORCE[a]	−0.19	−0.14	−0.08

[a] SBSHEAR = single blade shear; SBSAREA = single blade area; CBSHEAR = circle blade shear; CBSAREA = circle blade area; and COMFORCE = compression force.
* Significant at the $P < 0.05$ level.
** Significant at the $P < 0.01$ level.

Table 3—Overview of regression analyses with all five Instron readings as potential independent variables

Independent Instron	Dependent variables[a,b] Tenderness	Juiciness	Connective tissue
SHSHEAR		X	
SBSAREA	X		X
CBSHEAR	X		
CBSAREA			X
COMFORCE	X		X
R^2 (%)	92.6	33.2	95.7
S.E.E.	0.312	0.235	0.329

[a] An "X" indicates the independent variables that were ultimately selected by the stepwise procedure when the appropriate levels of significance were set at 5%.
[b] The overall sensory panel average evaluation and average Instron reading were used for each grade/cut combination. Consequently, there is one observation for each combination.

Statistical analysis

Results of this study apply only to the average panel responses and to the average readings obtained from the Instron machine and do not necessarily represent evaluations by a single panelist or a single machine measurement. We used the stepwise regression procedure, described by Draper and Smith (1966), to select the best regression equations. We also investigated results from the forward selection and backward elimination regression procedures of Draper and Smith (1966). Those two procedures usually produced the same regression equations as the stepwise procedure. Instron readings were used as independent variables and sensory panel traits as dependent variables. The appropriate levels of significance were set at 5%. Regression analysis was used solely to indicate which combinations of Instron readings were meaningful in predicting sensory panel traits. We place no particular importance on the specific values of the partial regression coefficients and have not included them in our results and discussion.

RESULTS & DISCUSSION

CROSS ET AL. (1976) reported significant differences at the 5% level of significance between the 16 grade/cut combinations for panelist evaluations of tenderness, juiciness and connective tissue (Table 1). Results of analysis of variance (not shown) indicated that the means of the 16 combinations differed at the 5% level of significance, for each type of Instron measurement. Evaluation of the relationship between palatability characteristics and Instron readings begins with the simple correlation coefficients in Table 2. SBSAREA and SBSHEAR were most highly correlated with sensory panel scores for tenderness and connective tissue amount. The relationship between compression force and sensory panel traits was low and nonsignificant.

In the first set of regression analyses, all five Instron readings were considered as potential independent variables (Table 3). The Instron readings explained 92.6% and 95.7%, respectively, of the variability of tenderness and connective tissue amount. The low R^2 for juiciness apparently reflects the inability of the Instron shear and compressive force measurements to meaningfully correlate with sensory juiciness.

In stepwise regression analysis, the resulting equation is highly dependent upon the specific potential independent variables that are submitted for analysis. Any changes in the number and type of potential independent variables can result in different equations. Because of this situation, different sets of independent variables were used. Overviews of the results of these analyses for tenderness and connective tissue amount are provided in Tables 4 and 5, respectively.

In Tables 4 and 5 use of area readings in combination (SBSAREA and CBSAREA) usually gave slightly higher values of R^2 than use of shear readings (SBSHEAR and CBSHEAR)—equations 2 and 6 versus equations 1 and 5. The same situation existed when a third Instron variable (COMFORCE) was added—equation 4 versus equation 3 in Table 4—and the values of the R^2's were not markedly increased.

For readings from either the single blade or the circle blade, either the area or shear values are meaningful alone, but not together. That finding is a direct result of the high correlation (not shown) between shear and area readings from the same device.

Some plots (not shown) of Instron readings versus palatability characteristics indicated that the relationship was slightly curvilinear and, therefore, suggested that the squares of those readings might improve the regression equations (data

Teble 4—Overview of regression anelyses for sensory penel tenderness

	Independent varieble[a,b]						
Eq	SBSHEAR	SBSAREA	CBSHEAR	CBSAREA	COMFORCE	R^2 (%)	S.E.E.
1	X		X			84.0	0.440
2		X		X		84.3	0.436
3	X		X		X	90.4	0.356
4		X		X	X	91.6	0.333

[a] An "X" indicates the independent variables that were ultimately selected by the stepwise procedure when the levels of significence were set at 5%.

[b] The overall sensory panel average evaluetion and average Instron reading were used for each grade/cut combinetion. Consequently, there is one observation for eech combination.

Teble 5—Overview of regression enalyses for sensory panel connective tissue

	Independent variable[a,b]						
Eq	SBSHEAR	SBSAREA	CBSHEAR	CBSAREA	COMFORCE	R^2 (%)	S.E.E.
5	X		X			91.2	0.451
6		X		X		93.0	0.403
7		X		X	X	95.7	0.329

[a] An "X" indicates the independent variables that were ultimately selected by the stepwise procedure when the levels of significance were set at 5%.

[b] The overall sensory panel average evaluation and average Instron reading were used for each grade/cut combinetion. Consequently, there is one observation for each combination.

not presented). Squared terms were tested for the different regression procedures. Results of the regression analysis, however, indicated that the addition of squared machine readings as independent variables increased R^2 only slightly. We can, therefore, accept the basic machine readings as adequate for the regressions.

The shear force devices that we used for characterizing the texture of ground beef patties were acceptable and gave readings that were highly correlated with the sensory evaluation of patties. They were easy to use, allowed rapid testing of many samples and required relatively small samples. SBSAREA accounted for 79.2% and 86.5% of the variability in sensory panel tenderness and connective tissue amount, respectively (r^2, Table 2). Regression equations for data from three Instron measurements from three different devices, accounted for 92.6% and 95.7% of the variability in tenderness and connective tissue amount, respectively (Table 3). The best two-variable, two-device equations accounted for 84.3% (#2–Table 4) and 93.0% (#6–Table 5) of the variability in tenderness and connective tissue amount, respectively.

The use of more than one device gave meaningful increases in R^2 with associated decreases in the standard error. Measurements of the area under the peak curves for shear forces, as measured by the circle and single blades, seemed to offer the best compromise between the use of only one device or the use of three different devices.

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